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ABSTRACT

This guide is part of a series designed to help students learn about technology and teachers organize and improve instruction in technology. The instructional materials are based on the curriculum-alignment concept of first stating the objectives, developing instructional strategies for teaching those objectives, and assessing to those same objectives. The activities in this unit relate to constructing a space station model. The teacher edition includes the following components: suggested activities, learning activities sheet, teacher supplements, an optional assignment sheet, an optional activities module, answers to assignment sheets, written test with answers, and unit evaluation form. In addition, the teacher edition includes information on use of the publication, a competency profile, an instructional and task analysis, academic and workplace skill classifications and definitions, and a related academic and workplace skills list. The student edition contains a unit of study on construction technology that includes the following components: objective sheet, information sheet, assignment sheets, laboratory activity sheets, and student supplements. (KC)

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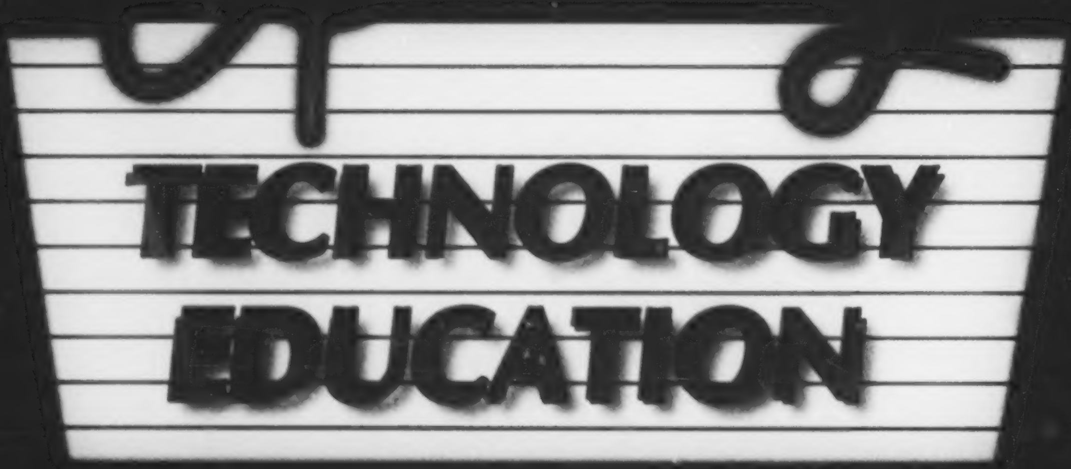

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Exploring Technology Education:

Exploring Construction Technology

Teacher Edition

Written by

John D. Joerschke, Technical Writer

Project coordinated by

Sue Jones, Curriculum Specialist
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

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Exploring Construction Technology

Teacher Edition

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Foreword

Exploring Technology Education: Exploring Construction Technology is one of five new publications that have been developed to replace MAVCC's original technology education series. The titles of the five new books in MAVCC's current technology education series are

- *Introduction to Technology Education*
- *Exploring Communication Technology*
- *Exploring Manufacturing Technology*
- *Exploring Construction Technology*
- *Exploring Energy, Power, and Transportation Technology*

The changes in the instructional materials in MAVCC's new technology education series reflect the changes that have occurred in industry as a result of emerging technology and the demand for more highly skilled workers who can read, write, find and interpret information, think creatively to solve problems, and then, effectively communicate their solutions to other people. As a result, the students who will use these instructional materials are asked to learn and use strategies for finding and presenting pertinent information and for thinking and problem-solving to complete the assignment and lab activity sheets that are the core of each unit of instruction in the series.

The success of this publication is due in large part to the capabilities of the personnel who worked with its development. Appreciation is extended to them for their valuable contributions to the publication.

These instructional materials are designed for student use and to assist instructors in organizing and improving instruction. These instructional materials are based on the curriculum-alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching those objectives (information, assignment, and lab activity sheets), and assessing to those same objectives (written test—a criterion-referenced evaluation instrument).

Every effort has been made to make these instructional materials basic, readable, and by all means, usable. However, as with all of MAVCC's instructional materials, instructors must localize and personalize these materials to meet their community, classroom/laboratory, and individual student's situation. Instructors are encouraged to supplement the instructional materials and to develop strategies for motivating their students.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improving the materials, please call or write us.

Jean McEntire, Chair
Board of Directors
Multistate Academic and
Vocational Curriculum Consortium

Clark R. Harris
Executive Director
Multistate Academic and
Vocational Curriculum Consortium

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Technology Education Instructor
Cleveland High School
Cleveland, Oklahoma

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Technology Education Instructor
Hobart High School
Hobart, Oklahoma

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Pawhuska, Oklahoma

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Technology Education Instructor
Olustee Jr/Sr High School
Olustee, Oklahoma

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Lynn Hawkins
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Donovan Bowers
Program Specialist

Harold Holley
Program Specialist

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Appreciation is also extended to the Agency for Instructional Technology (AIT) for providing the artwork used on the covers of the student and teacher editions of this publication.

Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information—such as the table of contents, foreword, and acknowledgments page—information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This profile should become a part of the student's permanent course records.
3. **Instructional/task analysis**—Provides a quick review of the contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.
4. **Academic and workplace skill classifications and definitions**—Defines the basic-skill classifications used by MAVCC. Skill areas reflected by skill groups, subskills, and definitions have been identified using *What Work Requires of Schools: A SCANS Report for America 2000 and Workplace Basics: The Skills Employers Want.* These have been adapted by MAVCC.
5. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and lab activity sheets) according to the related academic and workplace skills and competencies being reinforced.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

The instructional unit in the student edition of this publication includes the following components: objective sheet, information sheet, assignment sheets, lab activity sheets, and student supplements.

The teacher edition includes the following components: suggested activities, learning activities sheet, teacher supplements, an optional assignment sheet, an optional activities module (consisting of an optional information sheet, assignment sheet, student supplements, and a lab activity sheet), answers to assignment sheets, written test, answers to written test, and unit evaluation form.

Units of instruction are designed for use in more than one lesson or class period of instruction, all of the unit components focus on measurable and observable learning outcomes, and careful study of the components in both the student and teacher edition for each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for teacher demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Student-edition components

It is a challenge to keep students motivated. Instructors should supplement the student-edition components by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each of the student components listed below can best be taught, and by allowing students to become involved in preparing and planning their teaching/learning experiences.

Objective sheet. Each unit of instruction is based on performance objectives that state the goals for successful completion of the unit. These performance objectives are presented in two forms on the objective sheet: (1) a unit objective, which states the expected performance of each student after completion of the unit of instruction, and (2) specific objectives, which state what the student must do to reach the unit objective.

The instructor should stress the unit objectives throughout the teaching/learning process. Doing so will help answer student questions concerning performance requirements for each instructional unit. The objectives can also help the instructor determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives to an objective sheet in order to meet the needs of the students and community. When objectives are added, however, the teacher should remember also to add the needed information-sheet, assignment-sheet, lab-activity-sheet, and criterion-referenced written-test items.

Information sheet. The information sheet provides the students with the content essential for meeting the testable cognitive (knowledge) objectives of the unit; this means the cognitive information presented in the information sheet is tested in the criterion-referenced written test that is presented in the teacher edition for each unit of instruction.

Student supplements. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students must be able to apply in order to complete one or more of the assignment sheets or lab activity sheets in a unit of instruction. Students are not directly tested over the cognitive information presented in a supplement; however, their ability to apply this information should be evaluated in scoring the completed assignment sheet/lab activity sheet associated with a supplement.

Assignment sheets. The assignment sheets presented in a unit of instruction provide students with pencil-and-paper activities that give students the opportunity to apply the testable cognitive objectives presented in the information sheet and the nontestable cognitive information presented in student supplements. Criteria are provided on each assignment sheet to assist the instructor in objectively evaluating student performance.

Lab activity sheets. The lab activity sheets presented in a unit of instruction provide students with psychomotor activities that give students the opportunity to apply the testable cognitive objectives presented in the information sheet and the nontestable cognitive information presented in the student supplements.

A worksheet is included in each lab activity sheet. The worksheet provides criteria to allow the instructor to objectively evaluate student performance of the particular psychomotor skills presented in a lab activity sheet and also requires the student to check with the instructor to discuss the methods, equipment, and materials the student is planning to use in completing the psychomotor activity in that lab activity sheet.

Teacher-edition components

Suggested activities. The suggested activities component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan and a list of suggested resources to be used with each unit of instruction.

The teacher should read the instructional-plan section of the suggested activities component before presenting the unit to his or her students and decide how each objective can best be presented, how to obtain supplemental materials required for the unit presentation, and which outside resources will be required for the unit presentation.

The teacher should read both subsections of the "suggested resources" section of the suggested activities to obtain ordering information for books and media to supplement the subject area covered in a unit of instruction.

The subsection called "resources used in developing this unit" lists the books and materials that were used by the writer in doing research for a particular unit of instruction. These materials can be used by the teacher to supplement her or his knowledge of the subject area presented in the unit of instruction or to provide background information to students with particular interests or objectives in the subject area covered in the unit of instruction.

The "suggested supplemental resources" subsection provides ordering information for printed material or media presentations that instructors may want to use to supplement the subject area of the objectives presented in the unit of instruction.

Use of This Publication

Learning activities sheet. The learning activities sheet supplied in each unit is a step-by-step instruction sheet instructors may copy and distribute to students to guide their individual study through the required components in the student edition (objective sheet, information sheet, student supplements, assignment sheets, and lab activity sheets).

Teacher supplements. Teacher supplements are optional materials for the teacher to use. They may provide the teacher with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books or with information they may need to help students complete the required assignments/lab activities in the student edition.

Optional information sheet, optional assignment sheet, optional student supplement, and optional lab activity sheet. When these components are provided in the teacher edition for a unit of instruction, they are optional cognitive-information sheets, pencil-and-paper activities, and psychomotor activities. These optional activities may be duplicated for student use. They allow the instructor to use his or her discretion in providing students with additional objectives in the same subject area as the required objectives provided in the student edition.

Assignment-sheet answers. Assignment-sheet answers are designed to assist the teacher in evaluating student performances on both the required assignment sheets in the student edition and the optional assignment sheets in the teacher edition.

Written test. This component is a criterion-referenced evaluation of every cognitive objective listed in the information sheet in the student edition. If the instructor has added, deleted, or modified objectives in the student edition, appropriate changes should be made on the written test. The test is included in the teacher edition only, but duplication is permitted for student use.

Written-test answers. This component is designed to assist the teacher in evaluating student performance on the written test.

Unit evaluation form. This form provides teachers with a record of each student's performance on a unit of instruction. It includes space for assignment-sheet ratings, lab-activity-sheet ratings, written-test scores, and teacher comments. The unit evaluation form is included in the teacher edition only, but duplication is permitted for student use.

Competency Profile

Name: ______________________________

Directions: Evaluate the student using one of the optional rating scales below. Write the appropriate numbers/letters to indicate the degree of competency achieved. The descriptions associated with each of the numbers/letters focus on a level of student performance for each of the tasks listed. The written-test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Optional rating scales

Option A

Rating scale: 4 — **Skilled** – Can perform job with no additional training.
3 — **Moderately skilled** – Has performed job during training program; limited additional training may be required.
2 — **Limited skill** – Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** – Is familiar with process, but is unable to perform job.
0 — **No exposure** – No information or practice provided during training program, complete training is required.
NA — **Non-applicable**.

Option B

Yes — Can perform job with no additional training.
No — Is unable to perform satisfactorily.

Exploring Construction Technology

________ 1. Research a construction career

________ 2. Identify examples of the types of construction in your local area

________ 3. Practice drawing common building-material symbols

________ 4. Interpret a working drawing

________ 5. Evaluate a structure

________ 6. Design, build, test, and evaluate a model substructure

________ 7. Design, build, test, and evaluate a model truss-bridge superstructure

________ 8. Design and build a model modular structure

________ 9. ____

________ Written-test score

Continue to back of page.

Competency Profile

Comments: ____________________

____

____

____

____

Evaluator: ____________________ Date: ____________________

Permission to duplicate this profile is granted.

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Instructional/Task Analysis

Exploring Construction Technology

Related Information: What the student should know	Application: What the student should be able to do
1. Definition of the term *system*	10. Research a construction career
2. Definition of the term *construction system*	11. Identify examples of the types of construction in your local area
3. Definition of the term *construction technology*	12. Practice drawing common building-material symbols
4. Definitions of the stages in a basic technology systems model	13. Interpret a working drawing
5. Definitions of the types of construction	14. Evaluate a structure
6. Definitions of the major structural systems in a structure	15. Design, build, test, and evaluate a model substructure
7. Definitions of the stages in constructing a structure	16. Design, build, test, and evaluate a model truss-bridge superstructure
8. Common types of building materials	17. Design and build a model modular structure
9. Some of the emerging construction technologies	

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal or societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

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Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Resources	Time	Selecting relevant, goal-related activities; ranking them in order of importance; allocating time; and understanding, preparing, and following schedules.
	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Assessing skills and distributing work accordingly; evaluating performance and providing feedback.
Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position; accepting responsibility for others; and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women with a variety of ethnic, social, or educational backgrounds.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Related Academic and Workplace Skills List

Exploring Construction Technology

Task	Skill group	Subskill	Definition
Research a construction career (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Personal-management skills	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
Identify examples of the types of construction in your local area (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Practice drawing common building-material symbols (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
A. S. 3 (cont.)		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
		Processing	Using computers to acquire, organize, analyze, and communicate information
Interpret a working drawing (A.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
		Processing	Using computers to acquire, organize, analyze, and communicate information
Evaluate a structure (A.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
		Listening	Receiving, interpreting, and responding to verbal messages and other cues
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
A. S. 5 (cont.)		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way
		Interpretation	Selecting and analyzing information and communicating the results to others
		Processing	Using computers to acquire, organize, analyze, and communicate information
	Systems	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
Design, build, test, and evaluate a model substructure (L.A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
L. A. S. 1 (cont.)	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technological systems work and operate effectively
		Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies
Design, build, test, and evaluate a model truss-bridge superstructure (L.A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
L. A. S. 2 (cont.)		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technological systems work and operate effectively
		Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies
Design and build a model modular structure (L.A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others

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Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
L. A. S. 3 (cont.)	Systems	Interrelationships	Knowing how technological systems work and operate effectively
		Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies

Exploring Construction Technology

Suggested Activities

Instructional plan

Preparation

- Review the student components presented for this unit in the student edition.
  - Objective Sheet
  - Information Sheet
  - Assignment Sheet 1, "Research a Construction Career"
  - Assignment Sheet 2, "Identify Examples of the Types of Construction in Your Local Area"
  - Assignment Sheet 3, "Practice Drawing Common Building-Material Symbols"
  - Student Supplement 1, "Building-Material Primer"
  - Assignment Sheet 4, "Interpret a Working Drawing"
  - Student Supplement 2, "Introduction to Working Drawings"
  - Assignment Sheet 5, "Evaluate a Structure"
  - Lab Activity Sheet 1, "Design, Build, Test, and Evaluate a Model Substructure"
  - Student Supplement 3, "Introduction to Substructures"
  - Lab Activity Sheet 2, "Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure"
  - Student Supplement 4, "Introduction to Truss-Bridge Superstructures"
  - Lab Activity Sheet 3, "Design and Build a Model Modular Structure"
- Review the teacher components presented for this unit in this teacher edition.
  - Learning Activities Sheet
  - Teacher Supplement 1, "Using the AIT Media Programs"
  - Optional Assignment Sheet 1, "AIT Media Questions for Discussion and Review"
  - Teacher Supplement 2, "Test-Block Specifications"
  - Teacher Supplement 3, "Space-Station Historical Perspective"
  - Teacher Supplement 4, "Space Station Freedom Model Plan"
  - Optional Activities Module, "Plan and Construct a Model of Space Station Freedom"
  - Answers to Assignment Sheets
  - Written Test
  - Answers to Written Test
  - Unit Evaluation Form

The **Learning Activities Sheet** is a step-by-step instruction sheet you may copy and distribute to your students to guide their individual study through the required components in the student edition (Objective Sheet, Information Sheet, Assignment Sheets, Student Supplements, Lab Activity Sheets).

Suggested Activities

Note that Step 2 on the Learning Activities Sheets asks the student to obtain a copy of the questionnaire, "Questions for Discussion and Review," and Step 3 asks the student to watch unnamed media presentations and complete the questions for discussion and review.

You may obtain and show the AIT media presentations designed to go with this unit. **Teacher Supplement 1, "Using the AIT Media Programs,"** summarizes the content of these presentations (see the Suggested Supplemental Materials section below for ordering information.)

If you select the AIT presentations, write the names of those media presentations on the blank line in the Learning Activities Sheet, or if you have selected other media presentations to use with your class, write in the titles of those presentations.

If you use the AIT presentations, you may use **Optional Assignment Sheet 1, "AIT Media Questions for Discussion and Review,"** in Step 3, which asks students to complete questions for discussion and review. If you use other media presentations, you should prepare your own questionnaire to be used with Step 3 on the Learning Activities Sheet and title it "Questions for Discussion and Review."

Teacher Supplement 2, "Test-Block Specifications," gives you the specifications for the test block that you must build in order for students to complete Lab Activity Sheet 2, "Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure," in the student edition.

This supplement also lists the other items you will need to construct or collect to complete the testing system for the lab activity.

Teacher Supplement 3, "Space-Station Historical Perspective," Teacher Supplement 4, "Space Station Freedom Model Plan," and the **Optional Activities Module, "Plan and Construct a Model of Space Station Freedom,"** form a complete teaching package of both the teacher and student components necessary to guide your students through this optional construction activity.

Teacher Supplement 3, "Space-Station Historical Perspective," provides you with some background information on the history of space-station development—the early visionaries whose ideas lead to the eventual concept of a space station and some of the early stages that NASA has gone through in planning for the actual construction of Space Station Freedom.

Teacher Supplement 4, "Space Station Freedom Model Plan," provides you with some background information you will need to help your students complete the assignment sheet and the lab activity sheet in the student materials of the optional activities module.

The **Optional Activities Module** provides you with the student materials you will need to copy to hand out to your students if you choose to have your students plan and construct a to-scale model of Space Station Freedom.

Suggested Activities

- Modify the Learning Activities Sheet as needed to reflect your instructional plan. Copy and prepare the Learning Activities Sheet for distribution to your students.
- Copy and prepare the teacher components you select to distribute to your students (Written Test, Unit Evaluation Form).
- Prepare the classroom by putting up posters and charts and displaying articles and other references related to the objectives of this unit.

Delivery and application

Have students complete the steps in the Learning Activities Sheet, "Exploring Construction Technology."

Evaluation

- Evaluate the assignment sheets. See the evaluation criteria listed at the top of each assignment sheet as well as the teacher page **Answers to Assignment Sheets**.
- Evaluate the lab activity sheets. See the evaluation criteria listed on the worksheet that accompanies each lab activity sheet.
- Give the written test. See the teacher page **Written Test**.
- Evaluate the written test. See the teacher page **Answers to Written Test**.
- Compile written-test, assignment-sheet, and lab-activity-sheet scores. See the teacher page **Unit Evaluation Form**.
- Reteach and retest as required.

Suggested resources

Resources used in developing this unit

Print media

- Buck, Sue, Kevin Allen, and Eric Davis. *Exploring Aeronautics and Space Technology*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1991.
- Murray, Steve. *Exploring Technology Education*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1991.
- *Space Station Freedom Media Handbook*. Washington, D.C.: Office of Space Station, NASA Headquarters, April 1989.

Suggested supplemental resources

Nonprint media

- AIT media programs, copyright 1990:

  Introduction to Construction

  Designing and Planning a Structure

  Building a Structure

Suggested Activities

Finishing a Structure

Available from:

Agency for Instructional Technology (AIT)
Box A
Bloomington, Indiana 47402

Phone: (800) 457-4509 or (812) 339-2203

Exploring Construction Technology

Learning Activities Sheet

Put a checkmark in each blank as you complete each of the steps below.

_______ 1. **Read** Objective Sheet.

_______ 2. **Stop** Check with your instructor and obtain a copy of the questionnaire "Questions for Discussion and Review."

_______ 3. **Watch** Media presentations ______________________________

____

____

and

Complete "Questions for Discussion and Review."

_______ 4. **Study** Information Sheet.

_______ 5. **Do** Assignment Sheet 1, "Research a Construction Career."

_______ 6. **Stop** Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 7. If the evaluation is not satisfactory, repeat Step 5.

_______ 7. **Review** Information Sheet, Objective 5.

_______ 8. **Do** Assignment Sheet 2, "Identify Examples of Types of Construction in Your Local Area."

_______ 9. **Stop** Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 10. If the evaluation is not satisfactory, repeat Steps 7 and 8.

_______ 10. **Review** Information Sheet, Objectives 6 and 7.

_______ 11. **Read** Student Supplement 1, "Building-Material Primer."

_______ 12. **Do** Assignment Sheet 3, "Practice Drawing Common Building-Material Symbols."

_______ 13. **Stop** Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 14. If the evaluation is not satisfactory, repeat Steps 10, 11, and 12.

_______ 14. **Review** Information Sheet, Objectives 7 and 8.

_______ 15. **Read** Student Supplement 2, "Introduction to Working Drawings."

Continue to the next page.

Learning Activities Sheet

_______ 16. **Do** Assignment Sheet 4, "Interpret a Working Drawing."

_______ 17. **Stop** Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 18. If the evaluation is not satisfactory, repeat Steps 14, 15, and 16.

_______ 18. **Review** Student Supplement 2, "Introduction to Working Drawings."

_______ 19. **Do** Assignment Sheet 5, "Evaluate a Structure."

_______ 20. **Stop** Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 21. If the evaluation is not satisfactory, repeat Steps 18 and 19.

_______ 21. **Review** Information Sheet, Objective 6.

_______ 22. **Read** Student Supplement 3, "Introduction to Substructures."

_______ 23. **Review** Student Supplement 2, "Introduction to Working Drawings."

_______ 24. **Do** Lab Activity Sheet 1, "Design, Build, Test, and Evaluate a Model Substructure."

_______ 25. **Stop** Have your instructor evaluate the completed lab activity. If the evaluation is satisfactory, continue to Step 26. If the evaluation is not satisfactory, repeat Steps 21 through 24.

_______ 26. **Read** Student Supplement 4, "Introduction to Truss-Bridge Superstructures."

_______ 27. **Do** Lab Activity Sheet 2, "Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure."

_______ 28. **Stop** Have your instructor evaluate the completed lab activity. If the evaluation is satisfactory, continue to Step 29. If the evaluation is not satisfactory, repeat Steps 26 and 27.

_______ 29. **Review** Information Sheet, Objective 9.

_______ 30. **Review** Student Supplement 2, "Introduction to Working Drawings."

_______ 31. **Do** Lab Activity Sheet 3, "Design and Build a Model Modular Structure."

_______ 32. **Stop** Have your instructor evaluate the completed lab activity. If the evaluation is satisfactory, continue to Step 33. If the evaluation is not satisfactory, repeat Steps 29 through 31.

_______ 33. **Stop** Check with your instructor for any optional activities he or she may choose to assign.

Continue to the next page.

Learning Activities Sheet

_______ 34. **Do** Optional activities listed below.

_______ 35. **Stop** Have your instructor evaluate the optional activities. If the evaluation is satisfactory, continue to Step 36. If the evaluation is not satisfactory, repeat Step 34 as your instructor directs.

_______ 36. **Take** Written Test.

_______ 37. **Stop** Have your instructor evaluate the completed written test. If the evaluation is satisfactory, proceed to the next learning activities sheet. If your evaluation is not satisfactory, ask your instructor for directions for reviewing the information in this unit.

Permission to duplicate this form is granted.

Exploring Construction Technology

Teacher Supplement 1—Using the AIT Media Programs

Note A series of four AIT media programs was designed to supplement this unit, "Exploring Construction Technology." The first program in the series is "Introduction to Construction"; the second program is "Designing and Planning a Structure"; the third program is "Building a Structure"; and the fourth program is "Finishing a Structure."

Program name AIT media, "Introduction to Construction"

Program summary This program examines construction—its types, history, and relationship to other kinds of technology, society, and the environment. Defining construction as using people and resources to produce a structure on site, the program points out that homes are only one of the types of structures that may be built.

Students in classes are shown building construction models.

CAD-design processes, transportation and manufacturing of materials, and energy are all shown as being part of the construction process.

Some of the problems related to advancements in construction are discussed—in the 19th century, steel made vast construction projects possible, but these brought problems of overcrowding, traffic, and pollution.

The program introduces the different types of construction—residential, civil, and commercial.

Residential construction produces homes and apartments. An architect discusses the four stages of the design process and leads viewers on a tour of an apartment complex he has designed. The program demonstrates the application of the systems model to residential construction, in which the blueprint, materials, and energy are the input, the work of builders during the construction constitutes the process, the completed building is the output, and the response of residents and developers is the feedback.

Civil construction is for the use of everyone. The controversial Denver airport, offering both the promise of economic growth and the possibility of noise, pollution, and higher fares, is an example of civil construction.

Commercial construction is exemplified by a new middle school, seen both under construction and newly finished. Its finishing is described in terms of the systems model.

The program concludes by raising the possibility of construction by robots on the moon or Mars. Should we construct a new way of life on other planets? Would you want to live there?

Teacher Supplement 1

Program objectives

The media program is designed to illustrate

- the types of construction (residential, commercial, and civil)
- the effects of present and future construction technology on society and the environment
- the systems model for the construction process (input, process, output, and a feedback loop)

Program name

AIT media, "Designing and Planning a Structure"

Program summary

This program introduces the design and planning processes involved in construction: site considerations are shown to be important, and the teachers who will be using a new school are shown being consulted about important design considerations before construction of the school.

The program presents successful designs (Golden Gate Bridge) and unsuccessful designs (Tacoma Narrows Bridge), and shows technology students designing and constructing model bridges in a competition to see whose bridge is the strongest.

The students' bridge-building is shown to follow the systems model, in which their plans are the input, the process is the construction of the bridge with wood pieces and glue, the finished bridges are the output, and the feedback comes when the students see how well their bridges hold up in competition.

In another technology education class, students are shown engaging in underwater construction. Students are attempting to put together a geodesic dome to experience construction in a gravity-free environment. NASA technicians perform similar construction experiments to learn about techniques for building an orbiting space station.

Orville Simpson describes Victory City, his plan for a self-contained, low-energy, nonpolluting city of the future. In his plan, a single building over a mile long and over 100 stories high would house 260,000 people. Viewers are asked whether his ideas are utopian or a realistic possibility for the future.

Program objectives

The media program is designed to illustrate

- the primary considerations in the planning of structures—specifications, cost, and environmental impact.
- the techniques and equipment used in designing structures.

Teacher Supplement 1

Program name AIT media, "Building a Structure"

Program summary This program introduces the specific steps and processes used to prepare the site and erect the framework of a strong and safe structure. Different-sized buildings and sites require different kinds of foundations. When a foundation gives way, the building it supports will crumble. Viewers see speeded-up footage of a house being moved to a stronger foundation.

The first step in building a safe on-earth structure is to survey and prepare the site. A builder is profiled who explains that, in building a house, a footing of concrete is poured on solid soil below the frost line. A foundation wall of masonry blocks is built on the footing. The foundation wall may be waterproofed or insulated.

With time-lapse photography, viewers see floor joists, subfloor, and framing walls rise on the foundation. Ceiling joists, upper-story walls, and the roof are added to enclose the building.

Other structures, such as skyscrapers, are shown to follow a similar construction process, but stronger materials are required in this type of construction; for example, skyscrapers use steel instead of wood frames.

The idea is presented that the houses of the future will use more plastic compounds that offer flexibility and fire- and water-proofing. Viewers are asked to think of other ways plastics could be used in construction.

Program objectives The media program is designed to illustrate

- the basic steps involved in erecting a structure.

Program name AIT media, "Finishing a Structure"

Program summary This program introduces the process of finishing a structure inside and out and the three subsystems of a structure that are installed as part of the finishing process: (1) heating/cooling, (2) plumbing, and (3) electrical.

The program opens by showing a school under construction and explains the need for exterior and interior finishing before the building can be used. Rooms of the school under construction are contrasted with the same rooms six months later when they have been finished with insulation, soundproofing, glass, wall finishes, flooring, ceilings, lights, water, and heating.

Finishing is described in terms of the systems model: people, materials, and energy provide the input that undergoes the finishing process to result in a finished room; the feedback is the teachers' enthusiasm about their new building.

Footage shows the "House of the Future," as it was imagined 30 years ago. Then, viewers see the "Smart House" that has been designed by engineers today for maximum energy efficiency and control.

In the "Smart House," a single cable feeds the electrical systems, telephone, and stereo. Gas lines for heating, cooling, and cooking are controlled by computer modules. Safety is built into the electrical and gas systems. Residents get constant feedback about appliances' energy usage and cost. Residents are also shown controlling the systems in the house by calling in from the outside on a telephone.

The presentation concludes that, in the future, computers will be used more and more for planning, designing, and controlling the subsystems of structures. Viewers are asked how they believe such computerized systems will save builders time and money.

Program objectives

The media program is designed to illustrate

- the subsystems of a structure: (1) heating/cooling, (2) plumbing, and (3) electrical.
- the steps and materials used to finish a structure.
- how new technologies are improving the efficiency of the subsystems.

Exploring Construction Technology

Optional Assignment Sheet 1—AIT Media Questions for Discussion and Review

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Student responses are relevant and well thought out.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Directions As you watch each of the following AIT media presentations, answer the following questions in the space provided below each question.

Part A **AIT media, "Introduction to Construction"**

Discussion/ review questions

1. What is the definition of the term *construction*?

2. What examples of construction are shown in the media program?

3. How do the other three technology-system areas interrelate with the area of construction?

Optional Assignment Sheet 1

4. List and define the three types of construction, and then, describe examples of each type?

Type:

Definition:

Examples:

Type:

Definition:

Examples:

Type:

Definition:

Examples:

5. The terms of the universal systems model are input, process, output, and feedback. Apply these terms of the system model as they are presented in the media program by the building of the new school.

Optional Assignment Sheet 1

6. Describe some of the major stages in the history of construction that are presented in the media program.

7. What do architects do?

8. The media program ends by stating that, in the future, structures may be built on the moon or Mars. Do you believe that we should construct a new way of life on other planets? And, would you want to live on other planets? Explain your answers.

Part B AIT media, "Designing and Planning a Structure"

Discussion/ review questions

1. Discuss how you might begin planning for building a new school.

2. What are the results of good planning and design?

3. What are the results of bad planning and design?

4. Why were the students shown assembling pieces of pipe in a swimming pool?

5. How will an orbiting space station be constructed? What will be its purpose?

6. What problems might be solved by a city like Victory City?

Part C AIT media program, "Building a Structure"

Discussion/ review questions

1. Every structure has a foundation. What are the options when a bad foundation exists?

Optional Assignment Sheet 1

2. Why do builders in the Netherlands drive concrete posts deep into the earth when they build a structure?

3. What are the basic steps in building a house?

4. What is the definition of the term *footer*?

5. With a prebuilt wall, the framing and sheathing are done elsewhere and then the wall is brought to the building site. What are the advantages of using this type of construction?

6. Discuss ways plastics can be used in residential construction in the future.

Part D AIT media, "Finishing a Structure"

Discussion/ review questions

1. What is meant by the term *finishing*?

2. What are some of the materials used to finish the exterior of a structure?

3. What are some of the materials used to finish the interior of a structure?

Optional Assignment Sheet 1

4. List the reasons fiberglass insulation was used in finishing the school presented in the media program.

5. List the three types of subsystems of a structure that are installed as a part of the finishing process, and then, list some of the components of each subsystem.

Type:

Components:

Type:

Components:

Type:

Components:

6. Describe the finishing of the school in terms of the universal systems model—input, process, output, feedback.

Optional Assignment Sheet 1

7. List some of the finishes applied to the cafeteria, gymnasium, hallways, and swimming pool in the construction of the school presented in the media presentation.

8. Describe some of the features of the "Smart House."

Teacher Supplement 2—Test-Block Specifications

Introduction

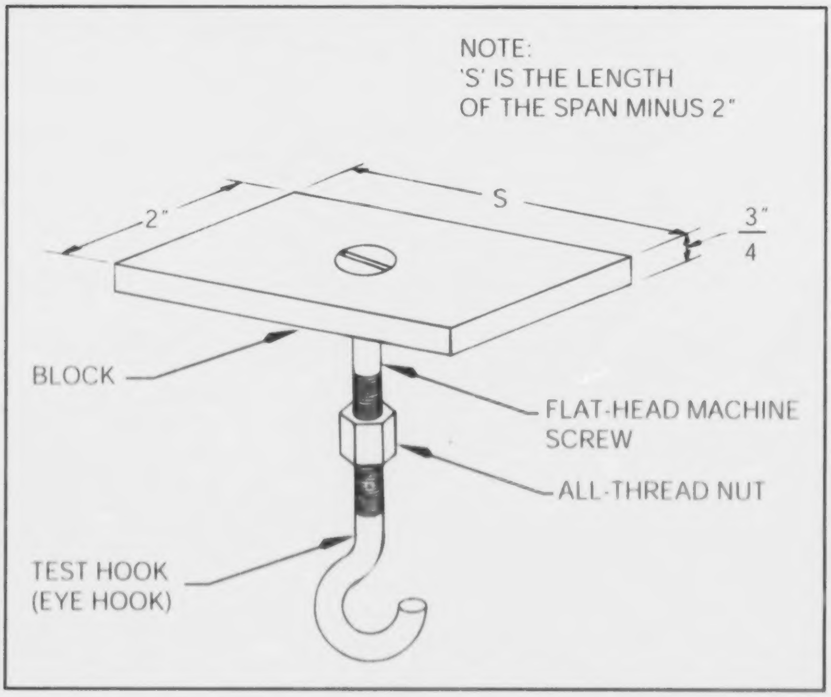
The test block shown in the diagram in Figure 1 below must be built by the instructor to be used by the students in completing Lab Activity Sheet 2, "Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure," in the student edition.

The test block is a part of a testing system you must build to allow students to stress-test their model truss-bridge superstructures. The complete testing system will include:

- a testing frame,
- the block, the machine screw, and the test hook/nut that create the test block (see Figure 1),
- a 5-gallon plastic bucket with a handle,
- 50 pounds of clean, dry sand, and
- a scale.

The students will build the roadbed of their superstructures to fit within the span of the testing frame and to accommodate the test block so that the machine screw can protrude through the roadbed and then the test hook can be attached with the nut.

Figure 1: Test block


NOTE:
'S' IS THE LENGTH
OF THE SPAN MINUS 2"

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Teacher Supplement 3—Space-Station Historical Perspective

Early visionaries

The concept of the space station goes back at least to 1869 when Edward Everett Hale mentioned in the *Atlantic Monthly* the "Brick Moon," a 60-meter-diameter satellite for a crew of 37 to help navigate ships at sea. Novelists like H.G. Wells and Jules Verne foresaw space travel in the late 1800s. By the turn of the century, scholars such as Konstantin E. Tsiolkovsky were laying the foundations of space travel to orbital stations (see Figure 1 on page 26).

The modern space-station concept dates back to 1923, when the Romanian-born Hermann Oberth published his theoretical treatise on the possibilities of large, liquid-fueled rockets. *Die Rakete zu den Planetenraumen* (The Rocket to Interplanetary Space) was the opening shot in a debate about the meaning of the space station that was to last for more than six decades. Oberth envisioned a voyage to Mars, and perceived that a refueling depot in outer space (or "weltraumstatin") would serve as a staging point for the journey. He quickly realized that a station in space could do many other things that would further justify its construction.

In the 1920s, other visionaries, mostly Germans, joined Oberth in his advocacy of this unheard-of technology. A space station was, at this time, symbolic of a wide range of Earth-orbital activity, such as astronomy, meteorology, cartography, and military reconnaissance. The word "weltramstatin" became a short-hand description for the entire gamut of orbital spaceflight technology.

Wernher von Braun was one such young enthusiast. A protege of Oberth, he rose in the 1930s to become the premier rocket designer/engineer of his time. Unfortunately, the cost of building a rocket—the first logical step into space—was so high that the only patron available was the state of Nazi Germany. Von Braun saw the V2 as an intermediate step toward the much grander vision of a manned mission to Mars. He and other visionaries, such as Krafft Ehricke, left Germany at war's end to work for the United States. Thus, serious space-station thinking came to the United States in 1945.

In the 1950s, many groups began to think of the immediate and practical uses of space—both civilian and military. Von Braun was in the forefront of the space race, but he dreamed of a space station in permanent Earth orbit that would satisfy a wide range of scientific, economic, and political objectives—and serve as a base for future missions to the Moon and to Mars. He postulated that to get to that step, the United States should first build a small test-bed orbital laboratory. Others agreed in principle, and the debate continued: How long should such an orbital laboratory last? What was its primary function—to test man, or technology, or both? How many crew? Would it be resupplied? What altitude and inclination? Should it be built in space or on the ground and deployed in space?

NASA

NASA, created in 1958, became the forum for the space-station debate. In 1960, space-station advocates from every part of the fledgling space industry gathered in Los Angeles for a Manned Space Station Symposium, where they agreed that a space station was a logical goal but disagreed on what it was, where it should be put, and how to build it.

Teacher Supplement 3

In 1961, President Kennedy decided that the Moon was a target worthy of the American spirit and heritage. A lunar landing had an advantage over a space station: everyone could agree on the definition of landing on the Moon, but few could agree on the definition of a space station. This disagreement was healthy. It forced station designers and advocates to think about what they could do, the cost of design, and what was necessary. What were the requirements for a space station? How could they best be met? The requirements review process started informally in 1963 and continued for 23 years. NASA officials asked the scientific, engineering, and business communities over and over again—What would you want? What do you need? The answers flowed in, and NASA scientists and engineers puzzled over how to organize these wants and needs into an orderly, logical sequence of activity. Was the station a laboratory, observatory, industrial plant, launching platform, or drydock? If it were all of these things, how much crew time should be devoted to each?

In the 1960s, working quietly in the shadow of the gigantic Apollo/Saturn program, space-station designers and planners began to come to grips with the tough questions of safety, hardware, money, and manpower. Working from 1964 through 1966, they settled on the modular approach: a pay-as-you-go program that offered something to everyone. With incremental funding, NASA managers could provide an incremental space station. Yet cost remained a problem. Design costs were always eclipsed by operations costs. The longer a station stayed up in space, the more it would cost to operate and resupply.

In 1967 and 1968, NASA planners started looking at an advanced logistics-vehicle concept for the space station. They already had a dependable transportation system (the Saturn rocket) to launch station modules. What they needed was a relatively inexpensive way to resupply the station. This reusable spacecraft would shuttle between Earth and the space station. Hence, the word "shuttle" was selected in the summer of 1968.

NASA officials felt that the station/shuttle combination served everybody's needs. The station had always been a logical step into space. The problem was that not everyone in the country agreed that developing space technology was a logical thing to do. The station program was caught in the shifting tides of politics and culture. Furthermore, the station and the shuttle began to be perceived as two separate entities, which had not been anyone's original intention. In 1970, plans to launch modules via Saturn technology were cancelled, and station designers were told to scale down their modules to fit inside the shuttle, which would now do double duty as launch and resupply vehicle.

Thus, in 1972, in the approval of a reusable space transportation system, the space-station concept itself was approved. The transportation segment, called the *space shuttle*, would be developed first. The space station itself would await the future. But before the shuttle could be developed and made operational for a space station, the Saturn rocket would be used as both launch vehicle and the spacecraft for America's first space station: Skylab.

Skylab was launched in 1973 and served as the test-bed for the first American experiments in long-duration, manned spaceflight. Even though Skylab had a short life and was not equipped for resupply of key expendable items, it did foreshadow the promise of a permanently manned laboratory in space. The Skylab effort proved humans could live and work in space for extended durations, and more than 100 different experiments in life and materials science and in earth and solar observation were conducted successfully.

With the first flight of the space shuttle, in April of 1981, a space station was again considered as the next logical step in manned spaceflight. In May of 1982, a Space Station Task Force was formed, and a year later they had an initial space-station concept (see Figure 2 on page 27).

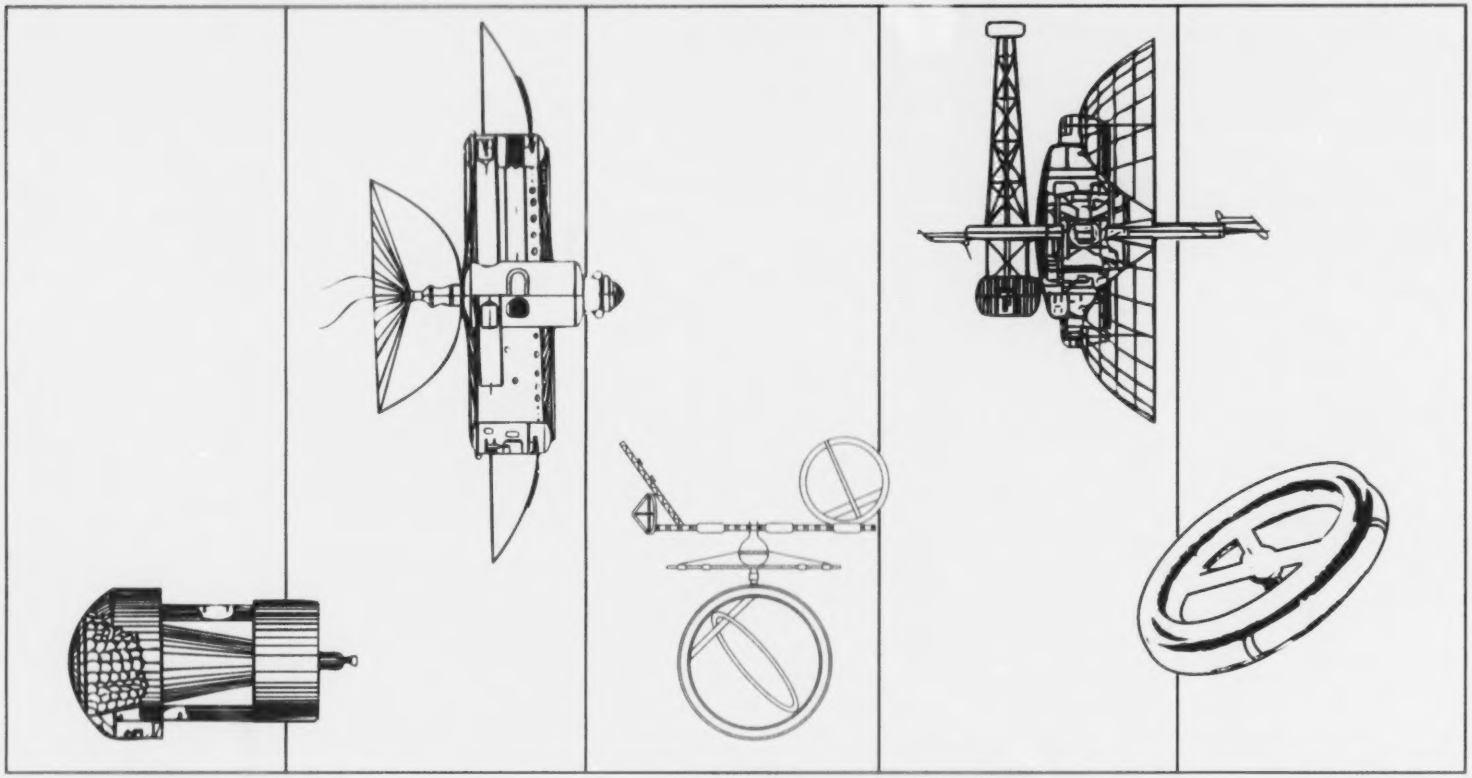
Cabinet-level departments and agencies studied the concept, and in January of 1984, President Ronald Reagan committed the nation to the goal of developing a permanently manned space station within a decade.

The Space Station Program Office was established in April of that year, and in April of 1985, eight contractors were selected to develop a detailed definition of the space station. In March of 1986, the Systems Requirements Review settled on a dual-keel configuration for the space station, affording a better microgravity environment, more capacity for attached payloads, and better location for the servicing bay than a single transverse boom. The U.S. reduced the number of their laboratory modules to one when the Europeans and Japanese decided to provide one each.

Although the definition and preliminary design phase ended in January 1987, the remainder of the year was spent conducting cost analysis, review of technical design issues, developing procurement packages, reviewing science requirements, developing operations concepts, and reporting to Congress and commissions. The Development Contracts were announced in December 1987. These efforts resulted in the baseline configuration that is shown in Figure 2.

Summarized from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Figure 1: Early space-station concepts



1900s
Konstantin Tsiolkovsky

1920s
Hermann Noordung

1930s
Hermann Oberth

1940s
Harry E. Russ and
Ralph A. Smith

1950s
Wernher von Braun and
Chesley Bonestell

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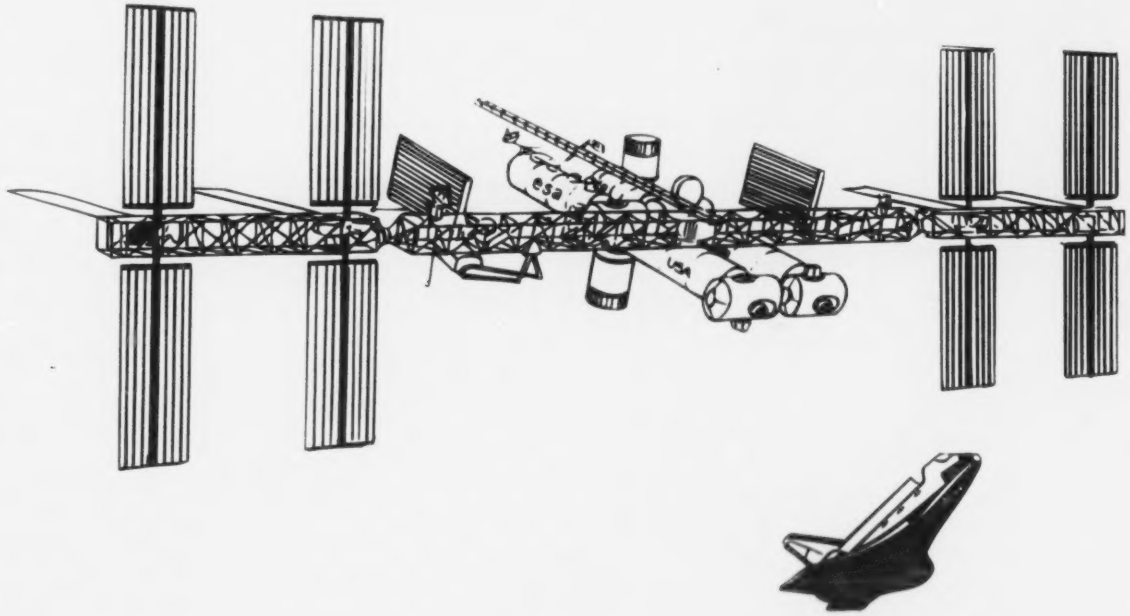
Figure 2: Space-station baseline configuration



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Teacher Supplement 4—Space Station Freedom Model Plan

Introduction

The following information is provided for your use in helping students complete the planning exercises in the optional activities module in Assignment Sheet 1, "Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom," and the assembly activity in Lab Activity Sheet 1, "Construct a To-Scale Model of the Major Structural Elements of Space Station Freedom."

The major structural elements of Space Station Freedom consist of the following:

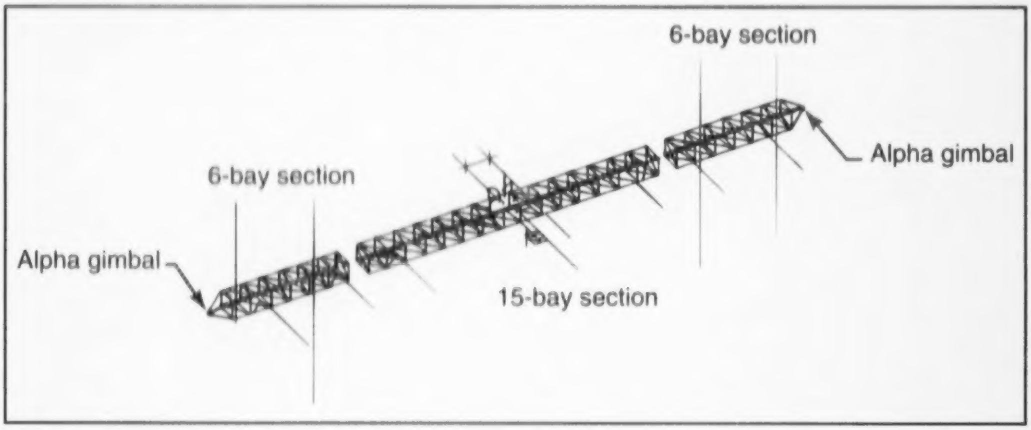
- Integrated-truss assembly
- United States Habitation Module
- United States Laboratory Module
- ESA Columbus Laboratory Module
- Japanese Experiment Module
- Logistic elements
- Resource nodes
- Photovoltaic power arrays
- Thermal radiators
- Mobile Servicing Center
- Space shuttle

Plan for completion of the model integrated truss assembly

In Student Supplement 4, "Constructing a Model Integrated-Truss Assembly," students will be shown one way to build an integrated-truss assembly. From this, students will learn the basic construction techniques necessary to complete the 27-bay truss that is required for the model space station. However, they will still need to make an assembly plan for creating the 27 bays. NASA's assembly plan for Space Station Freedom's truss is shown below in Figure 1. NASA's plan calls for a three-stage assembly consisting of two 6-bay outer sections and one 15-bay central section, which will be combined to form a 27-bay structure.

Using building components and other materials of your choice, have the class construct the 27-bay structure first and then attach alpha gimbals (see Student Supplement 4) at each end to complete the model truss assembly.

Figure 1: 27-bay structure and alpha gimbals



Teacher Supplement 4

Plan for figuring the scale of the structural elements

Once the truss assembly is finished, have students use the completed length of the assembly as a basis for figuring the scale of the remaining structural elements.

1. Have students measure the length of the model truss and then convert the measurement to inches, if necessary. Our completed truss-model components measured 9.5 feet, which converts to 114 inches, or

   9.5 feet x 12 inches/foot = 114.00 inches.

2. The actual length of the full-scale space station will be 508 feet. Convert this measurement to inches, or

   508 feet x 12 inches/foot = 6095 inches.

3. Divide the actual length of the space station (in inches) by the length of the model (in inches) to determine the scale of the actual truss to the model, or

   $$\frac{6096 \text{ inches}}{114 \text{ inches}} = 53.5, \text{ or}$$

   The scale of the actual truss to the model would be 1:53.5 (1 inch on the model equals 53.5 inches on the actual space station).

4. To calculate the scale size of each of the other model elements, use the following formula:

   (Actual length of element in ft. x 12 in./ft.) ÷ 53.5 = Scale size of element.

5. Actual dimensions of the various space-station elements are given in Table 1 below.

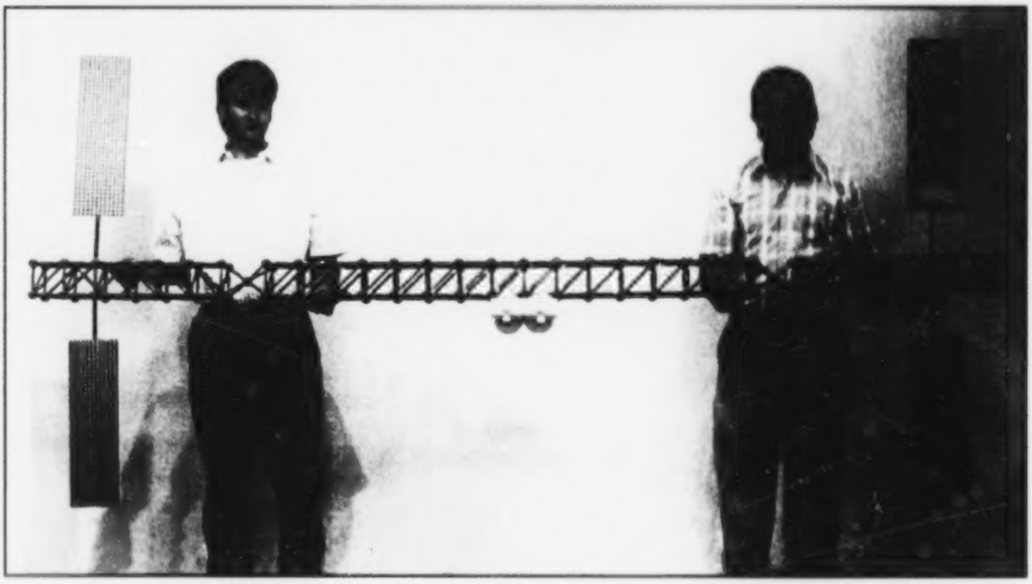
Table 1: Actual dimensions of space-station structural elements

Element	Actual dimension
Integrated-truss assembly	508 feet
U.S. Habitation Module U.S. Laboratory Module	44 feet long, 14 feet in diameter
ESA Columbus Laboratory Module	13 feet in diameter
JEM pressurized module	32 feet long, 13 feet in diameter
Logistic elements	14 feet in diameter, lengths will vary
Resource nodes	17 feet long, 14 feet in diameter
Photovoltaic power arrays	108 feet long, 34 feet wide
Thermal radiators	50-foot square
Mobile Servicing Center	20 feet long, 16 feet wide, height not yet determined
Space shuttle	121 feet long with a wing span of 79 feet

Equipment and materials listing

The following is a listing of the materials we used to construct the integrated-truss assembly, lab and habitation modules, and power arrays shown in the partially completed space-station model in Figure 2.

Figure 2: Partially completed space-station model



Lab and habitation modules

- Cardboard tubing
- PVC pipe
- Dowel rods
- Posterboard
- Cardboard

Solar array

- Cardboard
- Contact paper
- ¼-inch balsa wood
- Posterboard

Other tools and equipment

- Glue
- Disc sander
- Belt sander
- Band saw
- Hot-glue gun
- Fishing line

Integrated-truss assembly

- Plastic construction toys consisting of nodes and straight pieces

Optional Activities Module—Plan and Construct a Model of Space Station Freedom

Introduction

One of the most exciting challenges in construction technology now and in the future will be constructing permanently inhabitable structures in outer space, such as a space station.

The space station will be too large to launch in a space shuttle as a complete structure; it will have to be assembled on site in outer space. Even so, the space station will be completed using some of the same construction principles and technologies that are applied here on earth. The challenge will be in finding ways to adapt present principles and technologies, develop new technologies, and apply them in space.

This optional activities module includes the following instructional components you will need to plan and construct a model of the space station:

- Optional Information Sheet
- Optional Assignment Sheet 1, "Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom"
- Optional Student Supplement 1, "Space Station Freedom Assembly Plan"
- Optional Student Supplement 2, "Futuristic Perspective"
- Optional Student Supplement 3, "Space Station Freedom Management Plan"
- Optional Lab Activity Sheet 1, "Construct a To-Scale Model of the Major Structural Elements of Space Station Freedom"
- Optional Student Supplement 4, "Constructing a Model Integrated-Truss Assembly"

Completing the activities in this optional activities module will help your students understand the special challenges of applying construction technology in space.

Optional Activities Module

Optional Information Sheet

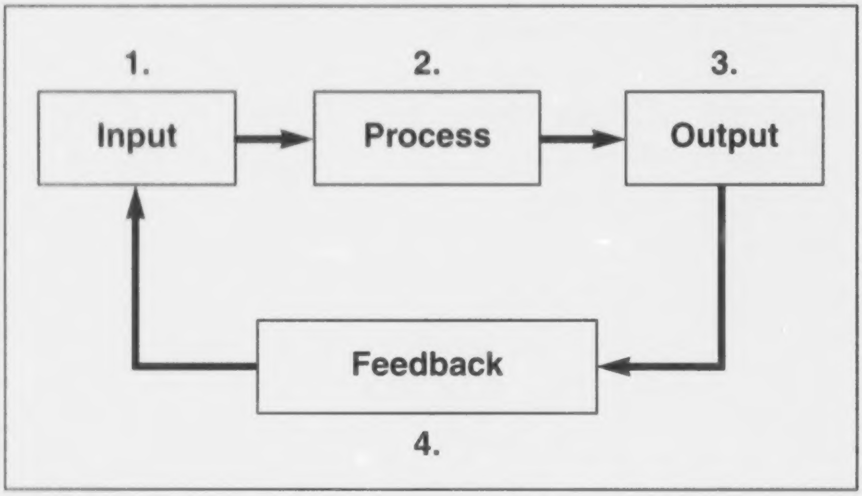
1. **Terms and definitions associated with space-station construction**

   - **Construction**—Production of a structure on site

   - **Structure**—Something made up of a number of parts that are held or put together in a particular way

2. **Components of the construction systems model and their definitions** (see Figure 1)

   Figure 1: Universal systems model



   - **Inputs**—People, knowledge, materials, energy, capital, and money

   - **Processes**

     — **Productive**—Preparing to build, designing the project, building the structure, installing systems, finishing the structure, completing the site and closing the contracts, and servicing the project

     — **Managerial**—Planning, organizing, directing, and controlling

   - **Output**—Structure

     Example: Space station

   - **Feedback**—Customer/user response, profit and loss, and quality control

3. **Definition of the term *construction technology***

   - **Construction technology**—Effective use of materials, labor, equipment, methods, and management resources to produce a structure on site

Optional Information Sheet

4. Objectives of space-station design

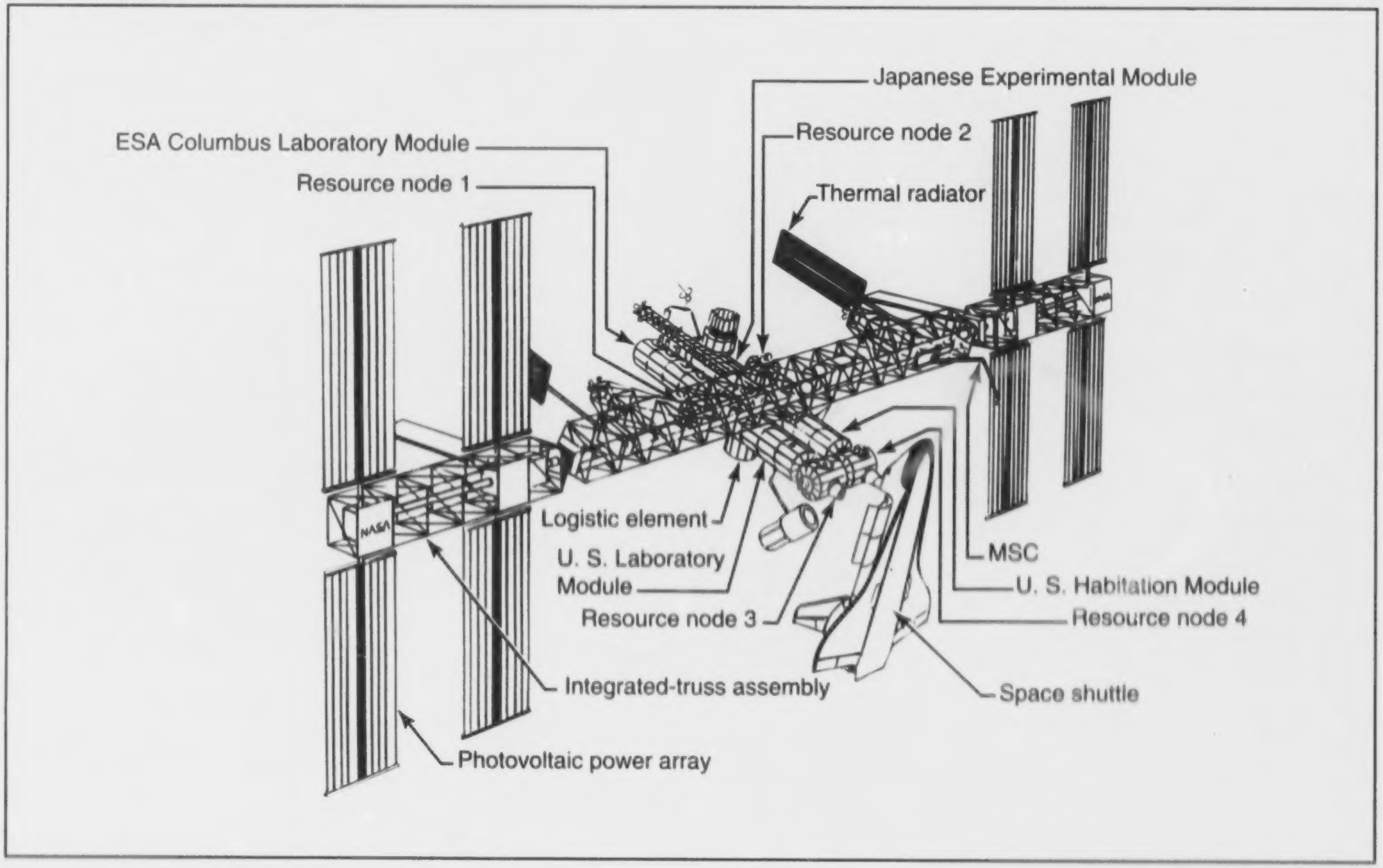
Note: The following objectives for a space station were based upon the needs expressed by many potential users over a six-year design phase. These objectives have guided NASA's overall activities on the project and have given direction to the technical analysis necessary to complete the overall design of the project. Upon completion, this multipurpose station will meet a wide range of NASA mission requirements as well as those of other federal agencies, private organizations, and foreign governments.

A space station will be

- A **laboratory** for conducting scientific research and developing new technologies
- A **permanent observatory** to look down upon the Earth and out into the universe
- A **servicing/repair facility** where payloads and spacecraft are resupplied, maintained, upgraded, and repaired
- An **assembly facility** where large payloads and vehicles are stationed, processed, and launched to their destinations
- A **manufacturing facility** where space-age products can be made
- A **storage depot** where payloads and parts are kept in orbit for subsequent deployment
- A **staging base** for future endeavors in space, such as a lunar laboratory or a base on Mars

5. **Major space-station structural elements and their definitions** (see Figure 2 and Figures 5 through 10)

Figure 2: Space-station baseline configuration


Japanese Experimental Module
ESA Columbus Laboratory Module
Resource node 2
Resource node 1
Thermal radiator
NASA
Logistic element
U. S. Laboratory Module
MSC
U. S. Habitation Module
Resource node 3
Resource node 4
Integrated-truss assembly
Space shuttle
Photovoltaic power array

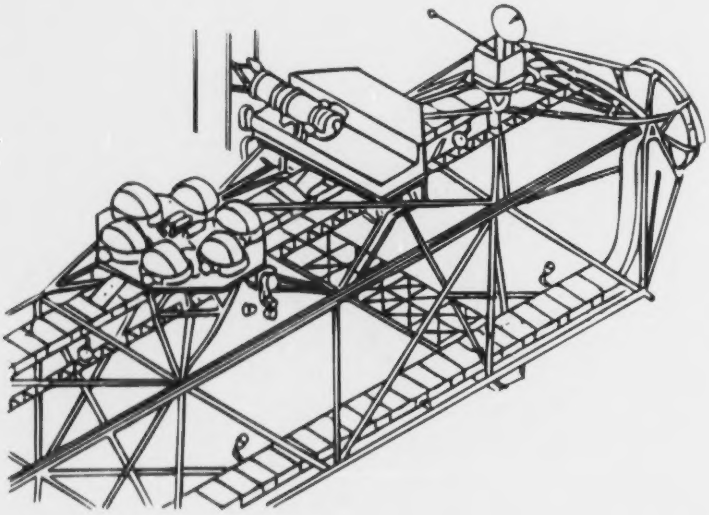
Reprinted from the National Aeronautics and Space Administration publication *The Space Station Power System*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., n.d.

Optional Information Sheet

- **Integrated-truss assembly**—Framework and attachment point for other space-station elements (see Figure 3)

Note: The integrated-truss assembly will provide the framework for the core base of the space station. It will serve as the attachment point for the photovoltaic power arrays, as well as other systems, including experiments. It will also facilitate the movement of crew and equipment, and provide for distributed systems.

Figure 3: Integrated-truss assembly



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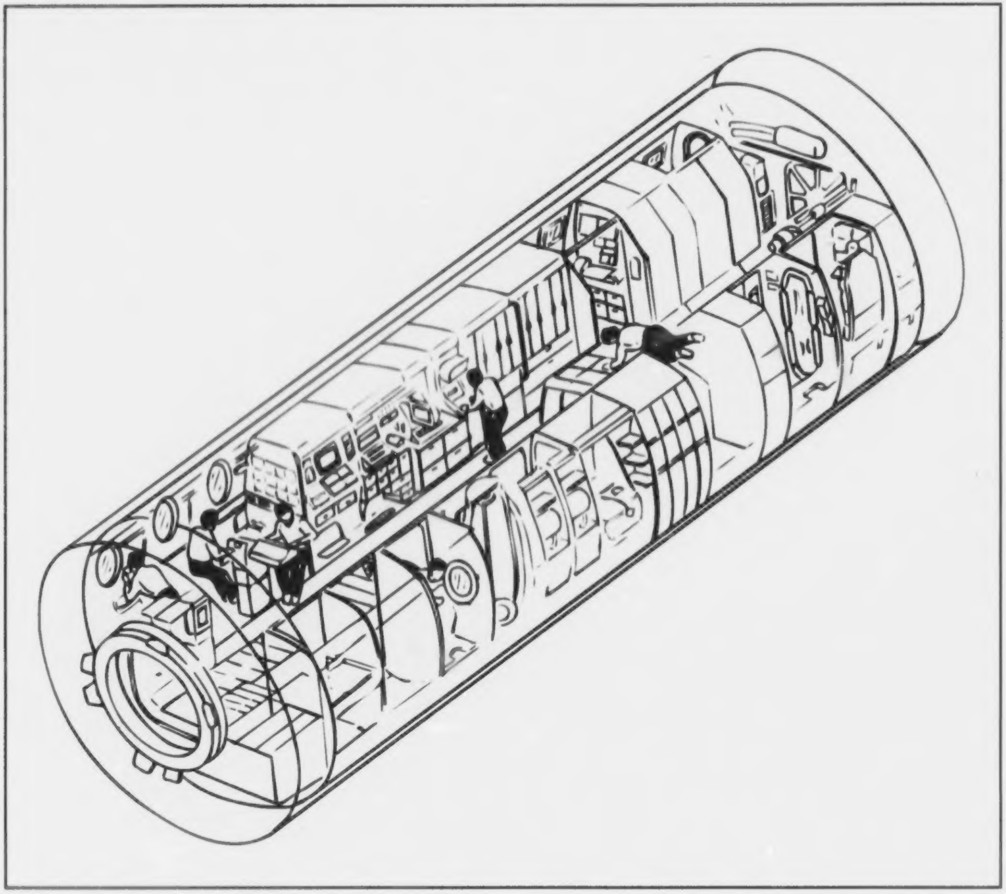
- **Laboratory and habitation modules**—Pressurized cylinders to provide astronauts with living quarters and research centers for conducting materials research, life-sciences research, and other space-science investigations

Note: In all, four pressurized modules are planned. The United States will provide one habitation module and one laboratory module; Japan and the European Space Agency (ESA) will each provide two other laboratory modules.

Equipment in the **U.S. Laboratory Module** (see Figure 4 on the next page) will include furnaces for growing semiconductor crystals, electrokinetic devices for separating pharmaceuticals, support equipment for low-gravity experiments, and a centrifuge for variable-gravity experiments in life sciences. The **U.S. Habitation Module** (see Figure 2) will provide up to eight astronauts with quarters for eating, sleeping, personal hygiene, waste management, recreation, and health maintenance.

Figure 4: U.S. Laboratory Module



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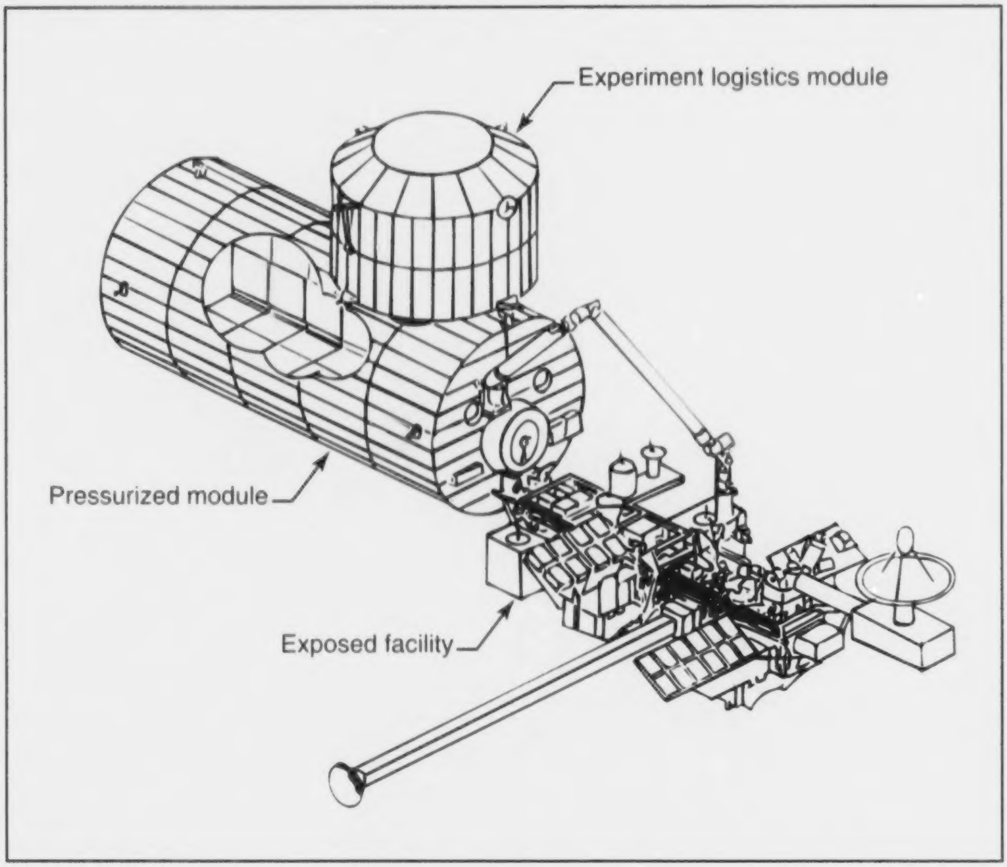
The ESA's **Columbus Laboratory Module** (see Figure 2) will be permanently attached to the space station's manned base. It will be used primarily for materials sciences, fluid physics, and compatible life-sciences missions.

The **Japanese Experiment Module** (JEM) (see Figure 5 on the next page) will be a multipurpose laboratory consisting of three components: a pressurized module, an exposed facility, and an experiment logistics module. Materials-processing experiments and life-science experiments will be performed in the pressurized module and it will also be the control and monitoring center for experiments performed on the exposed facility. Scientific observation, communication experiments, scientific/engineering, and materials experiments will be conducted on the exposed facility. The Experiment Logistics Module will provide on-orbit storage and a means of transporting logistics supplies such as experiment specimens, gases and fluids, and equipment and space parts for maintenance.

Optional Information Sheet

Figure 5: Japanese Experiment Module (JEM)



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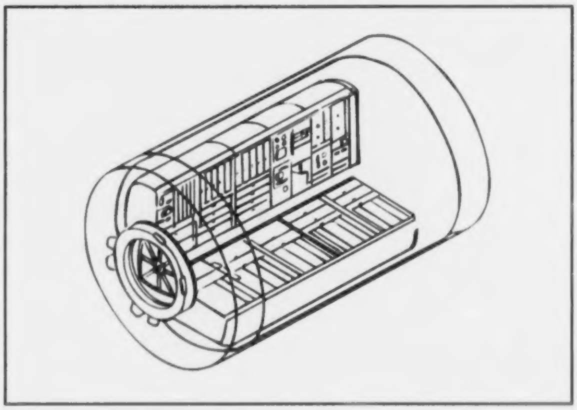
- **Logistics elements**—Replaceable cargo canisters attached to the station truss or to a module and designed to fit into the cargo bay of the space shuttle to transport equipment, supplies, and fluids to the station and to return experiment results, equipment, and waste products back to Earth

Note: The space station will require two kinds of logistics elements: pressurized and unpressurized. Pressurized logistics carriers (PLCs) will carry items requiring a habital environment. PLCs will transport life-science specimens (plants, etc.) to the station and then transport equipment, products, plants, biological specimens, and waste from the station. Unpressurized logistics carriers (ULCs) will transport payloads and equipment that do not need a pressurized environment. Typical contents in the ULCs will include platforms, payloads, and experiments for the station and fluids for the crew (see Figure 6 on the next page).

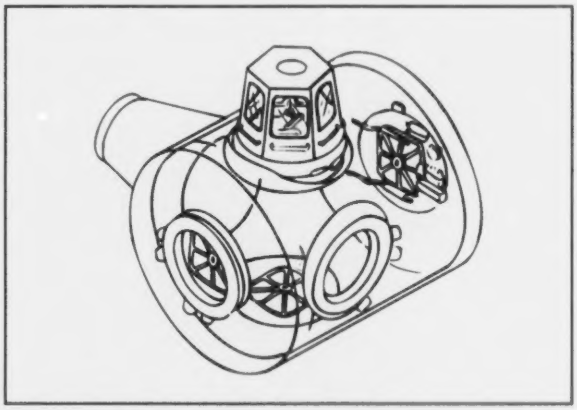
Optional Information Sheet

Figure 6: Logistics element



- **Resource nodes**—Pressurized cylinders designed to serve as command and control centers and as passageways to and from modules (see Figure 7)

Figure 7: Resource node



Figures 6 and 7 reprinted from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

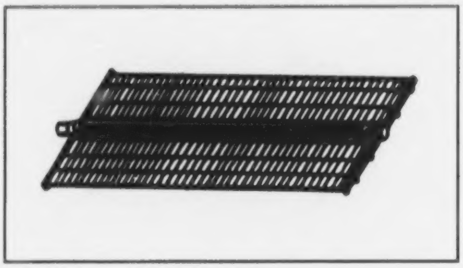
Note: The space station will contain four resource nodes (see Figure 2). Although the final configuration of the four nodes has not been determined, in the design stage, they were located as follows. Node 1 will be the control center for both unmanned flight and man-tended operations. It will be located between the U.S. Laboratory and ESA's Columbus Module. Node 2, located between the Habitation Module and the Japanese Experiment Module, will provide spacecraft and station back-up command and control work stations. Node 3 will likely be the primary command and central station for the pressurized modules and will be located at the forward end of the U.S. Laboratory Module. Node 4, connected to Node 3 and the forward end of the U.S. Habitation Module, will feature a cupola designed for proximity operations and berthing of the space shuttle.

Optional Information Sheet

- **Photovoltaic power arrays**—Panels of solar cells designed to provide the electrical power needed for space-station operations (see Figure 8)

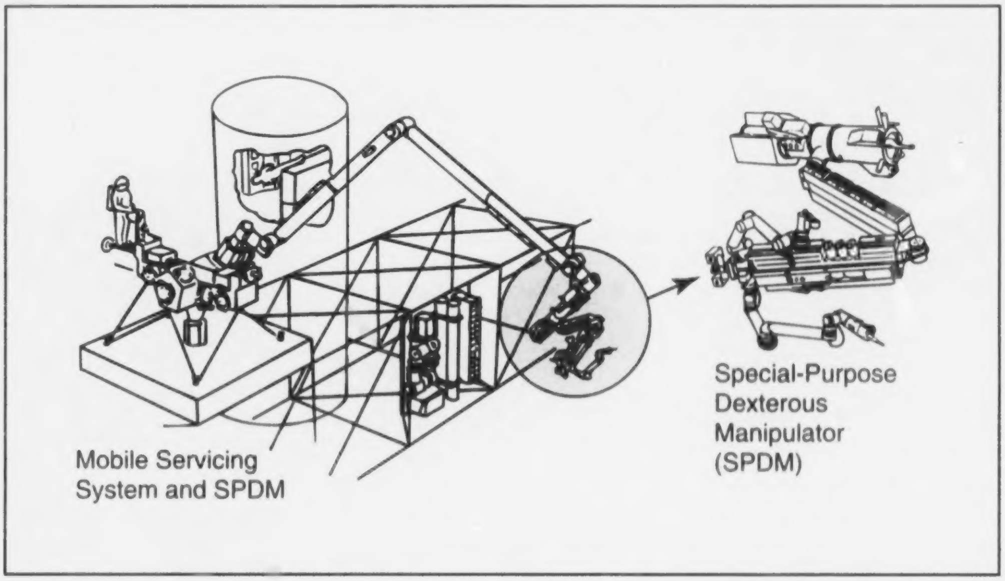
  Note: A series of eight power arrays (see Figure 2) will provide electric power aboard the space station during its early years. Each array will consist of two blanket assemblies, each covered with 14,592 solar cells.

  Figure 8: Power array



- **Thermal radiators**—Panels designed to interface with the environmental-control and life-support systems to remove excess heat from the atmosphere of the pressurized modules and nodes (see Figure 2)
- **Mobile Servicing Center** (MSC)—Rail-mounted center containing a robotic arm that will be moved along the truss to perform assembly and maintenance duties (see Figure 9)

  Figure 9: Mobile Servicing Center (MSC)


Mobile Servicing System and SPDM
Special-Purpose Dexterous Manipulator (SPDM)

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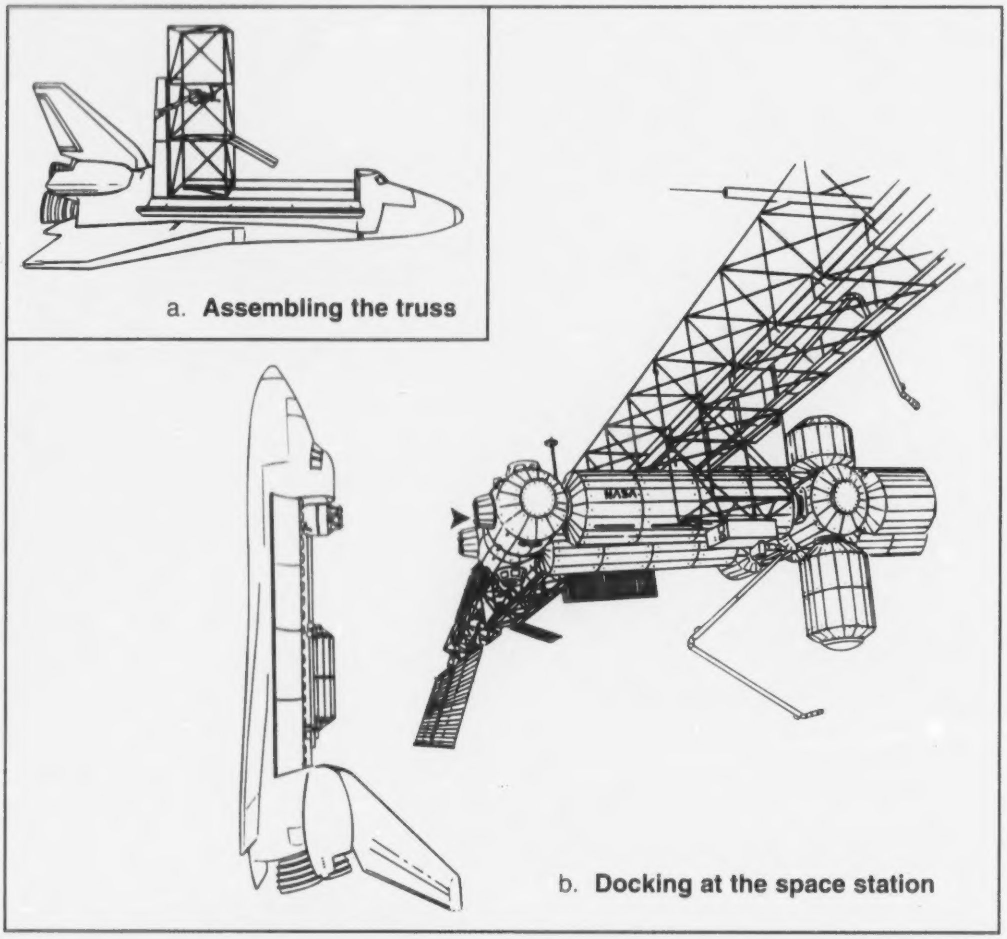
Optional Information Sheet

Note: Together with a U.S.-provided rail-mounted mobile transporter, the robotic arm to be supplied by Canada will play the main role in the space station's assembly and maintenance, moving equipment and supplies around the station, releasing and capturing satellites, supporting extravehicular activities, and servicing instruments and other payloads attached to the station. The MSC will also be used for docking the space shuttle to the station and then loading and unloading materials from its cargo bay.

- **Space shuttle**—Vehicle to transport the materials for the initial assembly and checkout of the space station and later to provide continued roundtrip transportation for crews and supplies between the Earth and the space station (see Figures 10-a and 10-b)

Figure 10: Space-shuttle uses



a. **Assembling the truss**

b. **Docking at the space station**

Figure 10-a reprinted from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Figure 10-b reprinted from the National Aeronautics and Space Administration publication *Space Station: Leadership for the Future* by Franklin D. Martin and Terence T. Finn, published by the Office of Space Station, NASA Headquarters, Washington, D.C., August, 1987.

Optional Information Sheet

6. Techniques to be used in space-station construction

- **On-earth construction**—Resource nodes, laboratory and habitation modules, logistic elements, solar arrays, and thermal radiators will be constructed on Earth and transported into space by the space shuttle. They will be finished products before they are transported and will need only to be attached to the integrated-truss assembly once in space
- **In-space construction**—The beams for the integrated-truss assembly will be manufactured on Earth, transported into space by the space shuttle, and then the integrated-truss assembly will be constructed in space

Optional Assignment Sheet 1—Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Management-structure table is complete and accurate and shows an understanding of the information presented in the student supplements.	______
Management-structure table is neat and well organized visually.	______
Assembly-sequence plan is complete and accurate and shows an understanding of the information presented in the student supplements.	______
Assembly-sequence plan is neat and well organized visually.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Introduction

The Space Station Freedom program plan integrates a wide variety of subsystem engineering, technology development, cost analyses and budgetary projections, international planning, and managerial experience into a coherent whole. Student Supplements 1, 2, and 3 describe some of the analysis and planning NASA has conducted in relation to this project. The extensive planning conducted has given NASA a good understanding of the productive and managerial issues involved, and as a result of this increased understanding, adjustments were made in the program before construction began. By making adjustments during the planning stages, NASA minimized the likelihood of having to make changes during construction, when changes could be extremely unsettling and very costly.

In Lab Activity Sheet 1, you will construct a complete model of the major structural elements of Space Station Freedom. Although this construction project will be on a smaller scale than the actual construction of Space Station Freedom, planning will play just as important a role in the successful completion of the project. The purpose of this assignment sheet is to guide you through that planning process.

Optional Assignment Sheet 1

Exercise

Activity checklist Put a checkmark on the blank line before each activity below as you complete it.

________ 1. **Read** Student Supplements 1, 2, and 3, which begin on page 47, to learn more about the productive and managerial processes NASA plans for the construction of Space Station Freedom.

________ 2. Your instructor will divide your class into groups. You and your group partners will use NASA's management structure shown in Table 1 in Student Supplement 3, "Space Station Freedom Management Plan," and the information discussed in the supplement as a guide in completing a **management-structure table** to use in planning the construction of your group's model space station.

Check with your instructor to see whether you should use a computer program or pencil and paper to complete your management-structure table.

________ 3. Using NASA's assembly sequence, which is discussed in Student Supplement 1, "Space Station Freedom Assembly Plan," as a guide, you and your group partners will complete an **assembly-sequence plan** to use in planning the construction of your model space station.

Again, check with your instructor to see whether you should use a computer program or pencil and paper to complete your assembly-sequence plan.

________ 4. **Turn in your management-structure table** and your **assembly-sequence plan** to your instructor for evaluation.

________ 5. Your instructor will return your management-structure table and your assembly-sequence plan with suggestions for improvement. **Make the improvements** your instructor suggests, and then, return your management-structure table and your assembly-sequence plan to your instructor for **final evaluation**.

Optional Student Supplement 1—Space Station Freedom Assembly Plan

Introduction

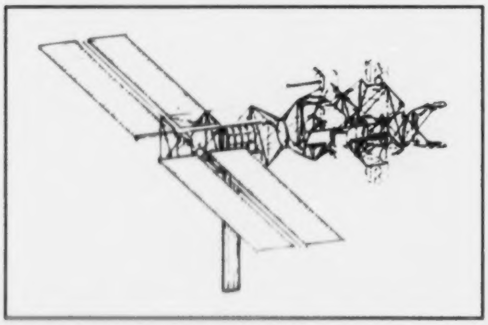
Space Station Freedom will weigh about half a million pounds and will be too large and heavy to be placed into orbit by one launch vehicle. Based upon the space shuttle's performance and payload-bay physical limitations, the current planning calls for approximately 20 shuttle flights to get all of the elements, systems, and support equipment to low Earth orbit. This assembly process will take about four years. The sequence in which these flights occur and packaging of selected parts are dependent on many factors. Early planning of the assembly sequence was based on various criteria such as utilization, manning, safety, power, and microgravity levels. The following is a brief description of Space Station Freedom's major assembly milestones.

The Manned Base assembly sequence of 20 space-shuttle flights has 4 major milestones. These events are planned to be accomplished close to the completion of the 1st, 4th, 13th, and 20th shuttle flights.

First-element launch (FEL)

The first cargo will consist of a set of integrated Space Station Freedom components to provide a fully functional spacecraft as the "cornerstone" for the fully assembled Manned Base. This "cornerstone" will be the starboard end of the Manned Base and includes a power module with solar panels and radiators, communications pallet with antenna, a reaction control system and tank farm, the mobile transporter, an assembly work platform, and associated truss and alpha joint structures. This integrated assembly will provide its own power and heat rejection, adequate orbital life, communications with the ground, and the capability to rendezvous and dock with the space shuttle for subsequent assembly flights (see Figure 1).

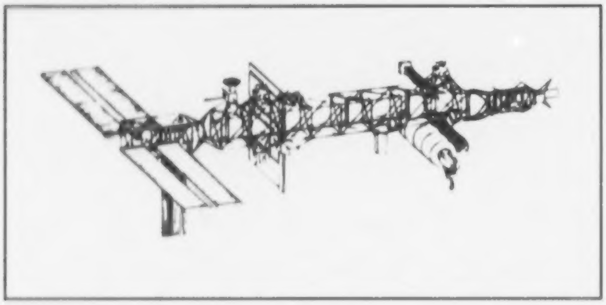
Figure 1: First-element launch (FEL)



Man-tended capability (MTC)

Upon completion of the 4th assembly flight, added structure will extend to the approximate center of the Manned Base and include the first-phase Mobile Servicing Center, a pressurized docking module, and the U.S. Laboratory Module outfitted to accommodate experiments. These added components and elements (see Figure 2 on the next page) will provide the Manned Base with an early man-tended capability until the next phase, permanently manned capability (PMC). The conduct of science and technology development in the U.S. Lab Module will be tended by astronauts on succeeding shuttle assembly flights.

Figure 2: Man-tended capability (MTC)

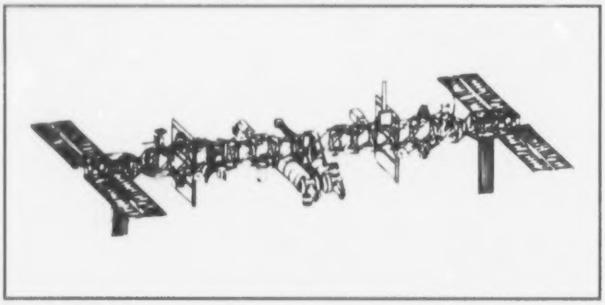


Permanently manned capability (PMC)

Upon completion of perhaps the 11th assembly flight, the complementing port side of the structure and components will have been added, including the inboard power module with solar panels and radiator, tank farm, reaction control module, and logistics modules, attached payloads and equipment from the extended-duration orbiter flights, aft and forward nodes with cupolas, airlocks, and the Habitation Module (see Figure 3).

Initial crew size will be at least four persons and will grow to eight when the international modules are attached. The crew will have the capability to live and work comfortably and safely in pressurized volumes indefinitely, and be able to perform full space-station-based extra-vehicular activities (EVAs). PMC will mark the beginning of full-scale manned-base operations on a day-to-day basis.

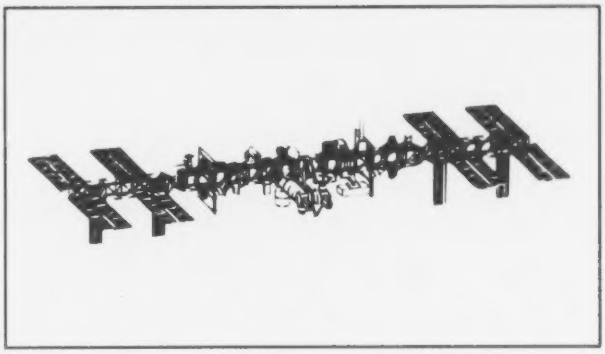
Figure 3: Permanently manned capability (PMC)



Assembly complete

Upon complete assembly of the manned-base (see Figure 4 on the next page), the Space Station Freedom Program will be a fully international space operation. The Japanese Experiment Module and the ESA Laboratory Module will be attached, and the Canadian Mobile Servicing Center will be in full operation. The crew will be fully integrated and composed of members from the four partners. Day-to-day operations will be centrally planned and coordinated through the Space Station Control Center and Payload Operations Integration Center, but execution of such activities will be initiated and controlled from remote-partner payload-operation centers as well as from on-board the manned base.

Figure 4: Assembly complete



Figures 1 through 4 and copy for Student Supplement 1 from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

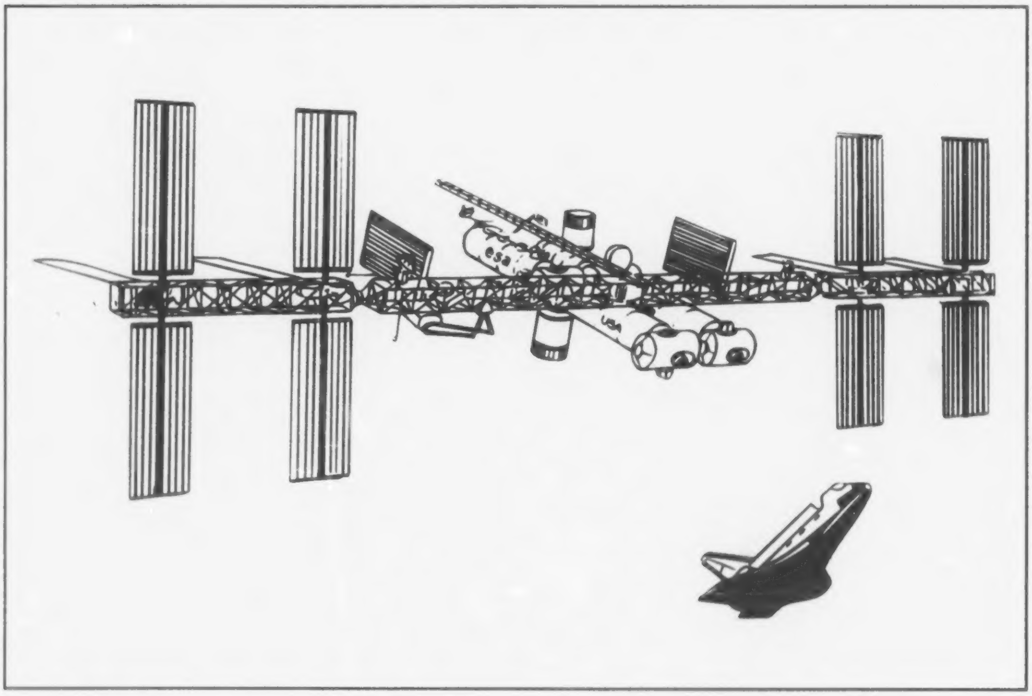
Optional Activities Module

Optional Student Supplement 2—Futuristic Perspective

Background

Evolutionary planning for the long-term use of the space station has been part of the program since the beginning planning stages—Phase A. At the very start, NASA's administrator called for the design of a "station we can buy by the yard," suggesting add-ons, developments, and enhancements. The Space Station Task Force included a "Year 2000" concept that showed growth of the preliminary design, and Phase B contractor studies included system requirements for evolution of the station. Early in the program, two Space Station Evolution Workshops were held in Williamsburg, Virginia, to explore station development. By 1985, it was decided that NASA Headquarters Office of Space Station should manage the evolutionary growth activities. NASA's Office of Exploration requested the Office of Space Station to look at the impacts of accommodating exploration missions. By 1987 the National Research Council Committee on Space Station endorsed the baseline configuration (see Figure 1) and urged NASA to continue to study "alternative evolutionary paths." A Presidential Directive on National Space Policy, issued on February 11, 1988, clearly states that the space station "will allow evolution in keeping with the needs of station users and the long-term goals of the U.S."

Figure 1: Space-station baseline configuration

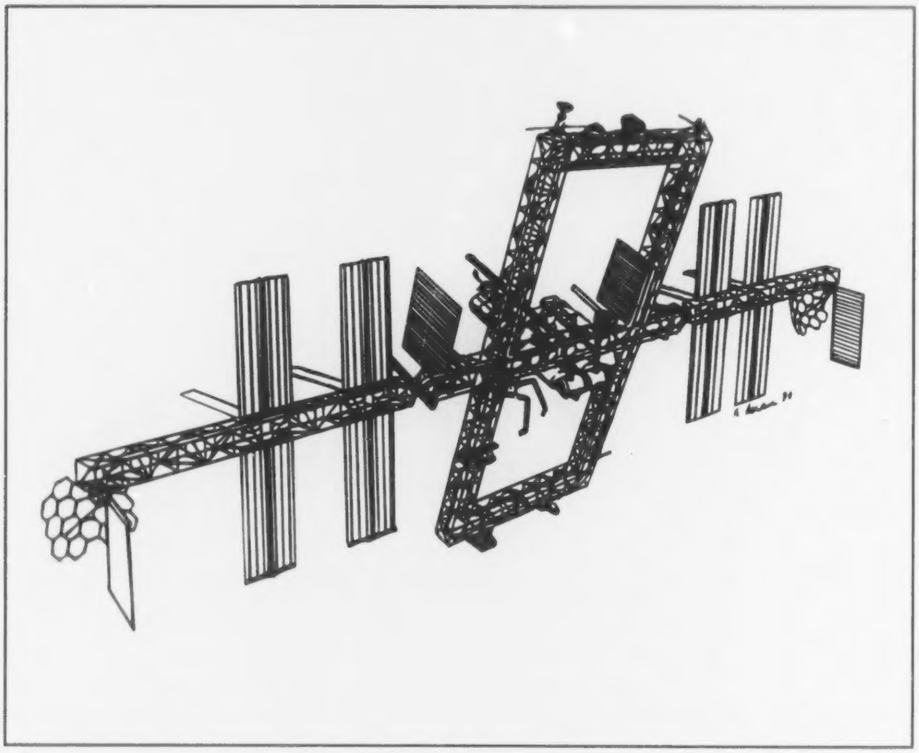


Optional Student Supplement 2

Hooks and scars From an engineering standpoint, these evolutionary changes will be accommodated by "hooks and scars." A *hook* is aerospace jargon for a design feature for the addition or update of computer software at some future time. Similarly, a *scar* is a jargon for a design feature to add or update hardware at some future time.

Future configuration The space station is being considered for enhancement sometime after the 20th assembly flight. The long transverse boom would be enhanced by two vertical keels about 105 meters long, and two 45-meter horizontal trusses at top and bottom (see Figure 2). This *dual-keel* configuration would add greater stability to the manned base, provide for many additional attached payloads, and offer a wide field of view for scientific instruments. Also to be included is a solar dynamic electric power system with an additional 50 kW. The Mobile Servicing Center (MSC) would be enhanced to handle heavier payloads.

Figure 2: Possible enhanced configuration



Optional Student Supplement 2

Lunar and Mars mission support

NASA scientists and technicians are developing scenarios on how the space station can support other explorations. The dual-keel configuration lends itself naturally to the function of a transportation node where spacecraft can be assembled, fueled, and checked out for manned missions to the Moon or Mars. Subsequently, such a spacecraft could be berthed, refueled, and repaired at the station upon its return. The space station could conduct much-needed research in bioregenerative life-support systems and artificial intelligence. The station could define the limits of human endurance for long-duration manned spaceflights in a weightless and hostile environment. The dual keel further lends itself to experimentation and as a quarantine facility before lunar and Martian samples are returned to Earth. Consequently, as space policy shifts, Congressional intent emerges, user demands change, and humans find new projects for outer space exploration, the space station is designed for evolution to meet these and yet-unheard-of uses for a 30-year, multipurpose facility in low Earth orbit.

Figures 1 and 2 and copy for Student Supplement 2 from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Optional Activities Module

Optional Student Supplement 3—Space Station Freedom Management Plan

Introduction

The Space Station Freedom program uses a three-tiered management structure. The three levels are as follows:

- **Level 1**, The Office of the Associate Administrator for the Office of Space Station (OSS) at NASA Headquarters in Washington, D.C.
- **Level 2**, the Space Station Program Office in nearby Reston, Virginia
- **Level 3**, the four NASA field-center project offices

This structure is shown in Table 1 on the next page.

Level 1

Policy and overall program direction

The Associate Administrator for the Office of Space Station at NASA Headquarters, Level 1, is responsible for the overall management and strategic planning of the program. Principal management responsibilities include

- Policy direction
- Budget formulation
- External affairs
- Space Station Freedom evolution

The Associate Administrator establishes and controls Level-1 technical and management requirements, milestones, and budget allocations and forecasts. Coordination of external affairs with both legislative and executive branches, user communities, and international partners, as well as internal units of NASA Headquarters that support the program, also falls under the jurisdiction of the Level-1 Office of the Association Administrator.

There are six divisions of Level 1:

- Information systems
- Resources and administration
- Policy
- Operations
- Utilization
- Strategic plans and programs

Optional Student Supplement 3

Table 1: Three-tiered management structure

LEVEL 1		LEVEL 1 SUPPORT CONTRACTOR (TADCORPS)
Office of Space Station, Washington, D.C.		Washington, D.C.
POLICY AND OVERALL PROGRAM DIRECTION		MANAGEMENT, ADMINISTRATIVE, OFFICE AUTOMATION, DOCUMENTATION, GRAPHICS
LEVEL 2		PROGRAM SUPPORT CONTRACTOR
Space Station Program Office, Reston, VA		Reston, Virginia
PROGRAM MANAGEMENT AND TECHNICAL CONTENT		GRUMMAN
LEVEL 3		CONTRACTORS
Various NASA Centers		Multiple Locations
PROJECT MANAGEMENT: ELEMENT DEFINITION AND DEVELOPMENT		DETAILED DESIGN, MANUFACTURING, INTEGRATION AND TEST, PLUS ENGINEERING AND TECHNICAL SERVICES
WORK PACKAGE 1 MARSHALL	• Lab Module • Hab Module • Node Structure • Logistics Carriers • Environmental Control & Life Support Systems • Certain Module Outfitting & Distributed Systems	Boeing
WORK PACKAGE 2 JOHNSON	• Truss Structure and Utility Runs • Propulsion System • Data Management • Thermal Control • Communication & Tracking • Attitude Control • Extra-Vehicular System	McDonnell Douglas
WORK PACKAGE 3 GODDARD	• Polar Platform • Payload Attach Points & Pointing Systems • Flight Telerobotic Servicer	General Electric
WORK PACKAGE 4 LEWIS	• Power Generation • Power Management and Distribution	Rocketdyne

Optional Student Supplement 3

Level 2 **Program management and technical content** (see Table 1)

The Space Station Program Office (SSPO), Level 2, is responsible for development of the space station, the operational capability of flight and ground systems, and the control of internal and external interfaces. Principal responsibilities include

- Systems engineering and analysis
- Program planning and resource control for both development and operations phases
- Configuration management
- Integration of elements and payloads into an operating system

This office is headed by the Director of the Space Station Program, who is responsible for the day-to-day management. The Jet Propulsion Laboratory (JPL) provides an independent program requirements and assessment function, attached to this NASA Program Office.

There are four offices and five groups in Level 2. The offices include

- Safety/product assurance
- Program support
- Program integration
- Program requirements and assessment

The groups include

- Program control
- Program information systems services
- Program utilization and operations
- Program systems engineering and integration
- International programs

In addition, there are two supporting offices from other NASA organizations: the accounting office and procurement office.

Level 3 **Project management: element definition and development** (see Table 1)

Level 3 consists of four Work Package Centers and their contractors, which are responsible for

- Design, development, testing, and evaluation (DDT&E)
- Operation of hardware and software systems
- Element, evolution, and engineering support

A Space Station Project Office is located at each of these Work Package Centers. The project managers of these offices report to the Director of the Space Station Program.

Optional Student Supplement 3

A Space Station Management Council assists the Associate Administrator in overseeing the program and advises on management, programmatic, and institutional matters. This management council is composed of the Associate Administrator for Space Station and the Deputy; the Director of the Space Station Freedom Program and the Deputy; and the Center Directors of the following NASA Centers:

- Marshall Space Center
- Goddard Space Flight Center
- Lewis Research Center
- Kennedy Space Center
- Langley Research Center
- Jet Propulsion Laboratory

Other advisory boards, groups, and committees are appointed as necessary and as the program situation dictates.

Work Package 1

The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, and its prime contractor, Boeing Aerospace, will design and manufacture

- The astronaut's living quarters—the Habitation Module
- The U.S. Laboratory Module
- The logistics elements
- The resource-node structures connecting the modules
- The Environmental Control and Life Support System
- The Thermal Control and audiovideo systems located within the pressurized modules

It also is responsible for the technical direction of the Work Package 2 contractor for the design and development of the engine elements of the propulsion system. In addition, MSFC is responsible for operations-capability development associated with space-station payload operations and planning.

Work Package 2

The Johnson Space Center (JSC) in Houston, Texas, and its prime contractor, McDonnell Douglas Astronautics Company, will manufacture

- The integrated-truss assembly
- The propulsion assembly
- The mobile transporter system
- The outfitting of the resource node structures provided by Work Package 1
- The EVA system
- The external thermal control system
- The attachment systems for the space shuttle and experiments packages
- The guidance, navigation, and control system
- The communications and tracking system
- The data-management system
- The airlocks

It is also responsible for the technical direction of the Work Package 1 contractor for the design and development of all manned systems. In addition JSC is responsible for flight crews, crew training, and crew emergency return definition, and for operation capability development associated with operations planning.

Work Package 3

The Goddard Space Flight Center in Greenbelt, Maryland, and its prime contractor, the Astro-Space Division of General Electric Company, will manufacture

- Servicing facility
- Flight telerobotic servicer
- Accommodations for attached payloads
- U.S. unmanned free-flyer platforms

Work Package 4

The Lewis Research Center in Cleveland, Ohio, and its prime contractor, the Rocketdyne Division of Rockwell International, will manufacture the Electrical Power Systems.

The above Work Package Centers will be supported by other NASA centers in fulfilling their responsibilities. For example, the Ames Research Center will provide supporting research and technology to Work Package 2 in the area of human factors and the EVA system.

Student Supplement 3 reprinted from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Optional Activities Module

Optional Lab Activity Sheet 1—Construct a To-Scale Model of the Major Structural Elements of Space Station Freedom

Introduction

Space Station Freedom will consist of the following major structural elements:

- Integrated-truss assembly
- The United States Habitation Module
- The United States Laboratory Module
- The ESA's Columbus Laboratory Module
- The Japanese Experiment Module
- Logistics elements
- Resource nodes
- Photovoltaic power arrays
- Thermal radiators
- Mobile Servicing Center
- The space shuttle

You reviewed the definitions and drawings of each of these major elements in Objective 5 of the information sheet. You will learn to construct a model integrated-truss assembly in Student Supplement 4, and as a member of a classroom group, you made plans for constructing a model of a space station in Assignment Sheet 1. As a group, you should now have at your disposal all the information you need to build a complete to-scale model of Space Station Freedom.

Procedure

Put a checkmark on the blank line before each step below as you complete it.

________ 1. Read the information presented in Student Supplement 4, "Constructing a Model Integrated-Truss Assembly," which begins on page 65, and review Objective 5 in the information sheet.

________ 2. Review your group's plans for constructing a model of the space station (as you completed in Assignment Sheet 1).

________ 3. You and your group members will build a model space station that includes all of the major structural elements of Space Station Freedom and that meets the rules and regulations for the activity, which are presented below.

Rules and regulations

- Your model space station must be constructed to scale.
- Your model space station must include all of the major structural elements in the list presented above in the introduction to this activity.

- Your group must follow the plans you created in Assignment Sheet 2 for constructing your space station.

_______ 4. Review the following worksheet associated with this lab activity.

_______ 5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for your space-station design and the equipment/materials you have listed for constructing the space station.

_______ 6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

_______ 7. Using the instructor-approved design and equipment/materials list, construct your model space station.

_______ 8. Have your instructor rate your performance using the evaluation criteria listed in Part B on the worksheet.

Optional Lab Activity Sheet 1

Worksheet—Construct a To-Scale Model of the Major Structural Elements of Space Station Freedom

Name ______________________________ Attempt number __________

Date ______________________________

Part A: **Pre-performance check**

Complete the following information concerning the design of the space station.

- On separate sheets of paper, draw a to-scale plan of the design of each of the major structural elements of the space station. On your design drawings, clearly label the scale you are using for your space-station plans.
- In the space below or on a separate sheet(s) of paper, list the equipment and materials you will require to construct each of the major structural elements of the space station, the quantities/amounts of each of the materials you will require, and the cost of each of the materials you will require, and the total cost of all the materials for the space station.

Instructor's signature ______________________________

Optional Lab Activity Sheet 1

Worksheet—Construct a To-Scale Model of the Major Structural Elements of Space Station Freedom

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Part B: Performance evaluation

Evaluation criteria	**Rating**
Design of the structural elements meets the rules and regulations set for the procedure.	______
Presentation of the design drawings is neat, accurate, and well organized visually.	______
Structural elements were constructed to scale and according to the plans the instructor had approved.	______
Lab clean-up and follow-up actions were satisfactory.	______
Overall rating	______

Evaluator's comments ____

____

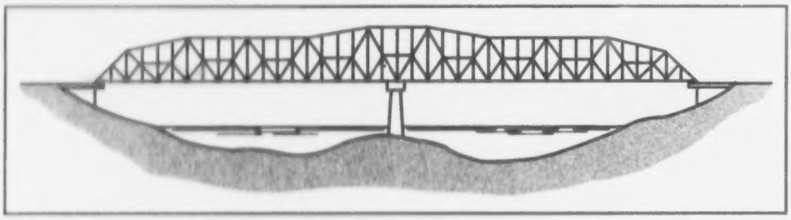
____

Optional Student Supplement 4—Constructing a Model Integrated-Truss Assembly

Introduction

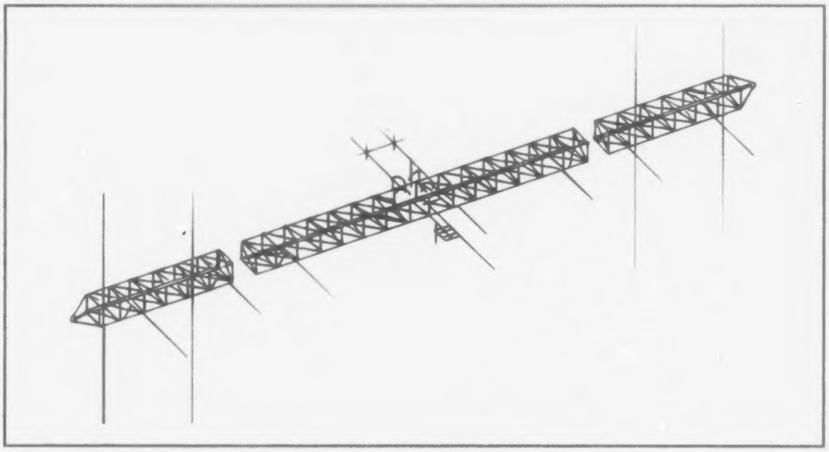
A *truss* is an assembly of members (beams, bars, rods) typically arranged in a triangle or a combination of triangles to form a rigid framework for supporting a load over a wide area. Trusses are often used on earth in the structural designs of bridges (see Figure 1). The space station will use a similar truss design for its main structural framework, called the *integrated-truss assembly* (see Figure 2).

Figure 1: Integrated-truss assembly



The integrated-truss assembly for the space station will consist of a framework of tubular beams forming a transverse boom, which, including solar arrays at each end, will measure 155 meters (508 feet). The 360-foot center of the boom will consist of a sequence of 5-meter (16.4-foot) cubic bays (see Figure 2).

Figure 2: Space-station integrated-truss assembly



Reprinted from the National Aeronautics and Space Administration publication Space Station Freedom Media Handbook, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Each bay cube will be formed by beams connected at attachment points called *nodes* (see Figures 3-a and 3-b on the next page). There will be a node at each corner of each cube, and adjacent bays will share four common nodes. Diagonal beams within each bay will form the triangles that create the traditional truss design (see Figure 4 on the next page).

Figure 3: Nodes

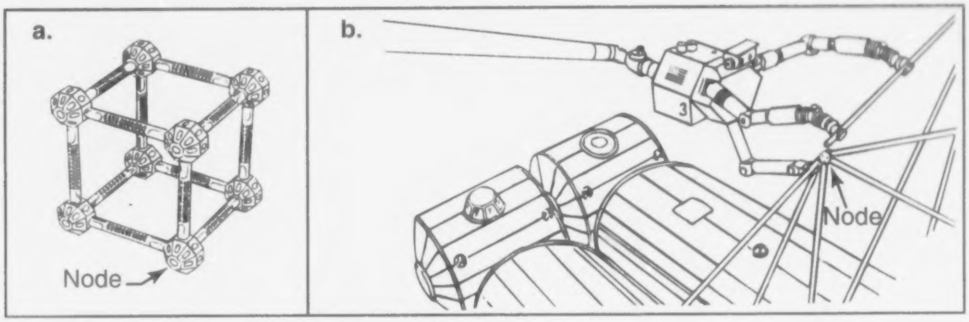


Figure 4: Diagonal beams

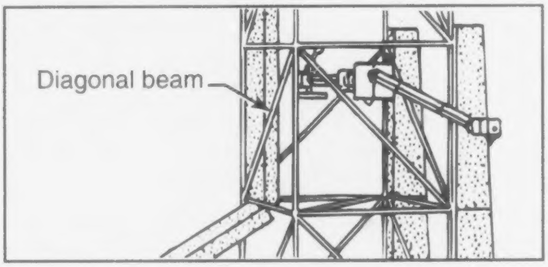


Figure 3-b and Figure 4 reprinted from the National Aeronautics and Space Administration publication *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Principle of truss design

One of the basic principles of truss design is that **the strength of a truss is based on the rigidity of its triangles**.

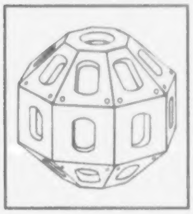
Equipment and materials

You will need the following components

- 37 nodes (see Figure 5)
- 62 short beams
- 41 long beams

Note: The artwork in Procedure A and Procedure B show components of a plastic construction system; these components are used only for an example. You may make your nodes and beams from any construction material of your choice.

Figure 5: Node



Optional Student Supplement 4

Procedure A Construct a 7-bay structure

1. **Construct a square.**

   a. Locate four nodes and four short beams.

   b. Place one node on the work surface and orient it so that the round holes are on top and bottom; locate the vertical faces of the node (see Figure 6-a).

   c. Insert the end of one short beam into a hole on a vertical face of the node; insert a second short beam on the vertical face of the node at a 90-degree angle to the first beam (see Figure 6-b).

   d. Orient and attach a second node at a 90-degree angle to the first beam inserted in Step c (see Figure 6-c).

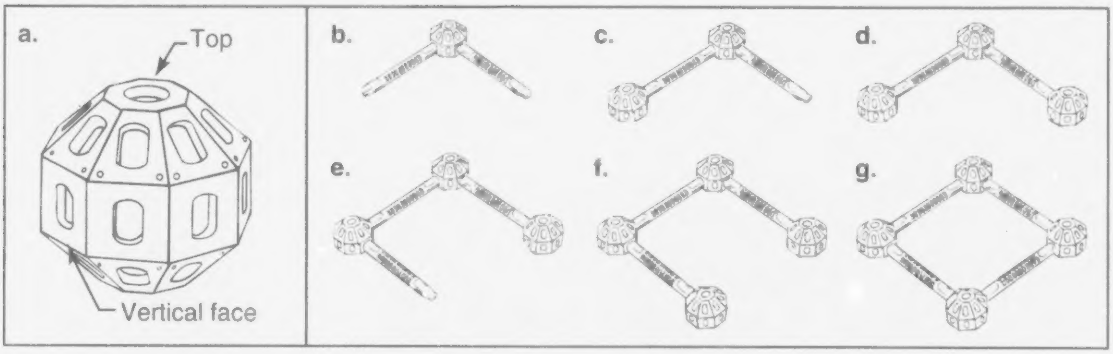
   e. Orient and attach a third node at a 90-degree angle to the second beam inserted in Step c (see Figure 6-d).

   f. Insert the end of one short beam into a hole on the vertical face of the node attached in Step c (see Figure 6-e).

   g. Attach a fourth node at a 90-degree angle to the short beam inserted in Step f (see Figure 6-f).

   h. Insert the remaining short beam between the vertical faces of the remaining unconnected nodes to form square (see Figure 6-g).

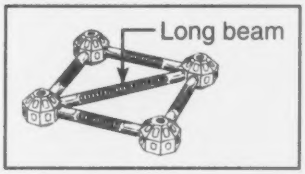
Figure 6: Constructing a square



2. Repeat Steps 1-a through -h until you have formed 8 squares.

3. Connect one long beam to form a diagonal between the two opposing nodes on each of the eight squares (see Figure 7 on the next page).

Figure 7



4. **Construct a cube.**

   a. Select one square and place it on the work surface so that the round holes in the nodes are on the top and bottom (see Figure 8-a).

   b. Insert a short beam into the top hole of each node (see Figure 8-b).

   c. Select one node and insert one long beam into a hole on a bottom angular face of the node so that the beam extends upward to the opposite corner to form a triangle (see Figure 8-c).

   d. Insert a second long beam into a hole on the bottom angular face of the node selected in Step c so that the beam extends upward to the opposite corner to form a second triangle (see Figure 8-d).

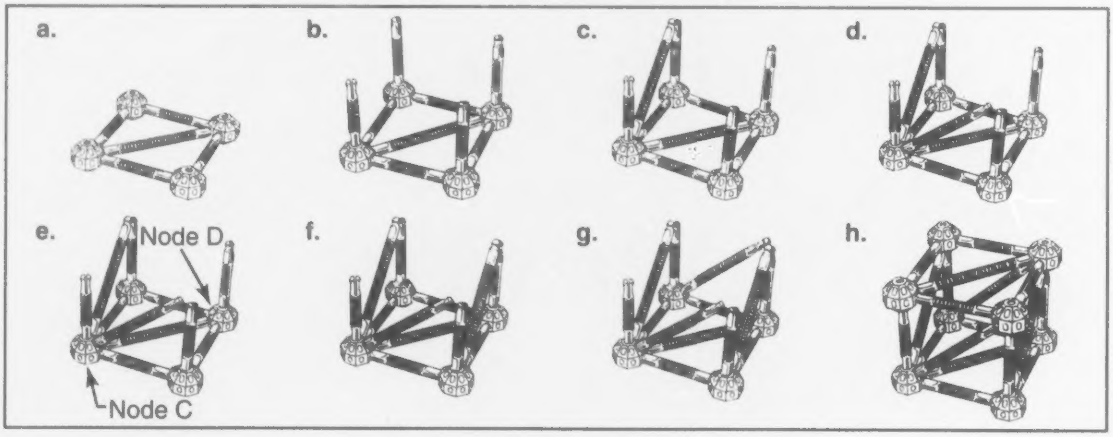
   e. Locate two nodes at the bottom of each triangle formed in Steps c and d (see Figure 8-e).

   f. Select one node located in Step e and insert a third long beam into a hole on the bottom angular face of the node so that the beam extends upward to the opposite corner to form a third triangle (see Figure 8-f).

   g. Select the second node located in Step e and insert a fourth long beam into a hole on the bottom angular face of the node so that the beam extends upward to the opposite corner to form a fourth triangle (see Figure 8-g).

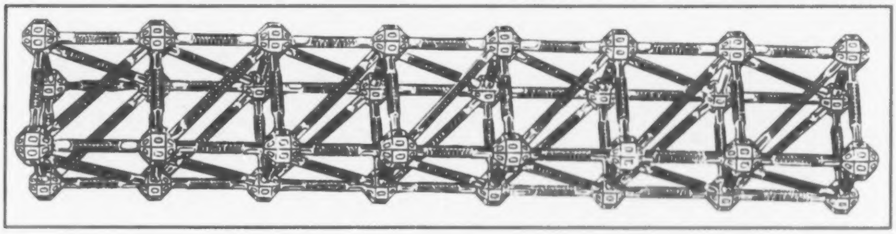
   h. Select another square and insert it on the beams to form a cube (see Figure 8-h).

Figure 8: Constructing a cube



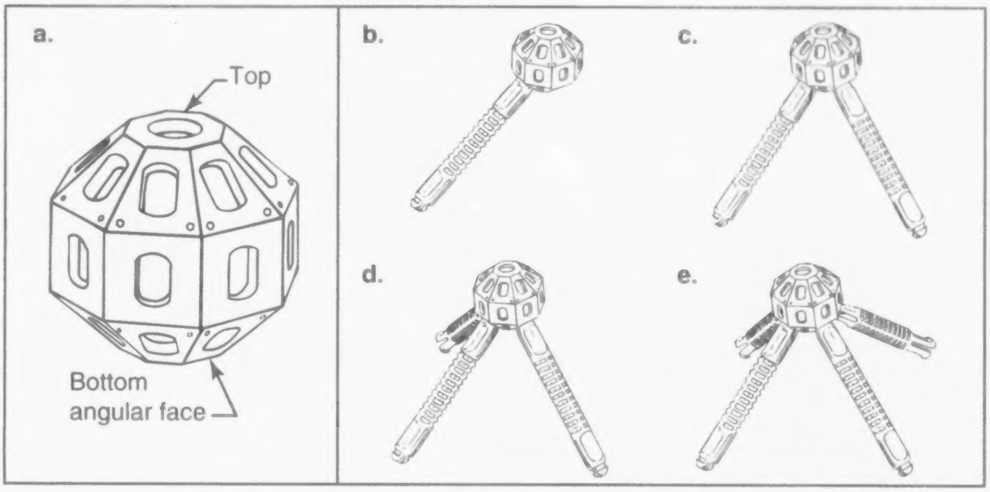
5. Repeat Steps 4-a through -h until you have constructed a 7-bay truss structure (see Figure 9).

Figure 9: Seven-bay truss structure



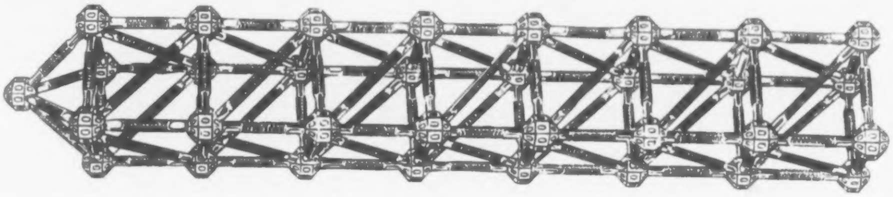
6. **Construct an alpha gimbal.**
   a. Locate one node and four short beams.
   b. Place the node on the work surface and orient it so that the round holes are on top and bottom; locate the bottom angular faces of the node (see Figure 10-a).
   c. Insert one short beam into a hole on a bottom angular face of the node (see Figure 10-b).
   d. Skip one hole on the node and insert a second short beam on a bottom angular face of the node (see Figure 10-c).
   e. Skip one hole on the node and insert a third short beam on a bottom angular face of the node (see Figure 10-d).
   f. Skip one hole on the node and insert a fourth short beam on a bottom angular face of the node to complete the alpha gimbal (see Figure 10-e).

Figure 10: Constructing an alpha gimbal



7. Insert the alpha gimbal onto the four nodes on one end of the 7-bay structure (see Figure 11).

Figure 11: Seven-bay truss structure with alpha gimbal



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Exploring Construction Technology

Answers to Assignment Sheets

Answers to required assignment sheets in student edition

Answers to Assignment Sheet 1, Assignment Sheet 2, Assignment Sheet 3, and Assignment Sheet 5—Answers will vary. Student performance should be evaluated according to the criteria listed on the assignment sheet.

Assignment Sheet 4

1. Floor plan
2. 30′ x 24′
3. 4″
4. Answers may appear in any order.
    - File room
    - Manager's office
    - Break room
    - Front office
5. 11′4″ x 11′8″
6. Two
7. Three
8. Two
9. None
10. a. 108
    b. 52
    c. 48
    d. $81.00 + $39.00 + $36.00 = $156.00

Answers to optional assignment sheets in teacher edition

Assignment Sheet 1, "AIT Media Questions for Discussion and Review"

Part A—AIT media, "Introduction to Construction"

1. *Construction* is using people and resources to produce a structure on site.
2. Roads, airports, bridges, houses, power plants, dams, schools, concert stages, monuments, water-treatment plants, space stations

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Answers to Assignment Sheets

3. Communication—Structures are designed by architects using CAD/CAM systems

   Energy, power, and transportation—Construction materials are transported to the construction site; energy runs machines and lights

   Manufacturing—Tools and equipment used in construction must be manufactured

4. Residential construction—Construction that produces structures people live in, such as single-family homes, apartments, and condominiums

   Civil construction—Construction that produces structures built to service the needs of citizens other than for shelter or residence, such as dams, bridges, railroads, pipelines, and airports

   Commercial construction—Construction that produces structures built for business, industry, government, and education, such as factories, stadiums, stores, malls, and schools

5. The **input** in the construction process involves the use of materials, people, and energy.

   The construction **process** involves transforming the construction materials into the structure—the finished school.

   The **output** is the finished school.

   The **feedback** is the students' responses and the teachers' reactions to the school, as well as the efficiency, durability, etc., of the finished structure.

6. First, caves were used for shelter; later, structures such as the Egyptian pyramids were made of stone; in the 1800s, steel began to be used in the construction of large structures.

   In addition to the many benefits brought about by the ever-improving methods of construction, these improved methods have also brought about overcrowding, traffic jams, and pollution.

7. Architects create designs and plans that show others how to build a structure. Architects may also contract for the work to be done to build the structure and supervise the construction process to ensure that their designs and plans are followed.

8. Answers will vary.

Part B—AIT media, "Designing and Planning a Structure"

1. Students may suggest questioning teachers and students about their needs, visiting other schools, reading about the latest school designs, making drawings, etc.

2. The results of good planning—Structures do what they are supposed to, for example, bridges last and withstand natural forces; buildings are comfortable to live and work in, are energy efficient, and are pleasing in appearance; highways are safe and require minimal maintenance.

3. The results of bad planning—Structures are unsafe, inefficient, uncomfortable, and inconvenient.

4. Students were participating in an underwater construction exercise to simulate construction in the weightless of space.

Answers to Assignment Sheets

5. The orbiting space station will be constructed of a series of modules manufactured on earth, transported by space shuttles into space, and assembled through the use of robotic arms and by astronauts. The space station will serve as living quarters for people researching the conditions in space and the new technologies that will be developed in space.

6. Cities like Victory City would help solve the problems of pollution, the loss of species of wildlife and plants because of urban sprawl and pollution, and the depletion of energy resources due to inefficient use.

Part C—AIT media, "Building a Structure"

1. When a bad foundation exists, it has to be reinforced or replaced, or the structure must be moved.

2. To set their foundations on bedrock, which is far below the wet, sandy soil

3. The basic steps in building a house are

   - Survey the site.
   - Locate and mark the site's boundaries.
   - Lay out the foundation for the house.
   - Excavate the site.
   - Pour the footings for the foundation.
   - Complete the foundation (lay the block for the foundation).
   - Install the sill plate.
   - Install the floor joists.
   - Lay the subfloors.
   - Raise the frame and the walls.
   - Frame the interior walls.
   - Install the ceiling joists.
   - Frame the roofing system, which consists of the rafters and trusses.
   - Finish the roofing system (add sheathing, tar paper, and shingles).
   - Enclose the house (add windows and doors).
   - Rough-in the electrical, plumbing, and heat/air subsystems.
   - Finish the exterior and interior surfaces of the house.
   - Landscape the site.

4. A *footer* is a part of the foundation, and it is used to distribute the weight of a structure over a large area.

5. With a prebuilt wall, the work can proceed indoors, regardless of the weather, and when the walls arrive on the site, the building can be enclosed very quickly.

6. Answer should include at least roof shingles, siding, molding, insulation, and wall panels, but students may come up with other correct answers also.

Part D—AIT media, "Finishing a Structure"

1. *Finishing* means installing the subsystems and applying materials to the inside and outside surfaces of the structure to improve the appearance of the structure.

2. Wood shingles, composite roofing, vinyl or aluminum siding, and masonry are some of the materials used to finish the exterior of a structure.

3. Wallboard or "sheetrock," paint, wallpaper, paneling, and flooring (hardwood, tile, carpet, or vinyl) are some of the materials used to finish the interior of a structure.

4. Fiberglass insulation was used in the walls of the school to reduce the noise levels in the building, to maintain the temperature (heat or cool air) inside the school, and to increase the safety in the building by reducing the spread of a fire should one occur.

5.
   - **Heating and cooling**—Some of the components are the ductwork, furnace, air-conditioner, and thermostat
   - **Plumbing**—The plumbing subsystem consists of the pipes, drains, water heaters, etc., that supply water to a structure and that remove used water and liquid waste from the structure.
   - **Electrical**—The electrical system consists of the wiring, circuits, switchboxes, etc., that supply electrical energy to the house for lighting and to power electrical appliances for recreation, personal care, and food preparation.

6.
   - **Input**—People, materials, energy
   - **Process**—Installing the construction materials, finishing, and installing the subsystems
   - **Output**—The finished building
   - **Feedback**—The response of the students and teachers to the new school

7.
   - **Cafeteria**—Painted walls, tiled floors, windows, lights
   - **Gymnasium**—Wood floor, bleachers, lights
   - **Hallways**—Carpeted floor, handrails, lockers, lights
   - **Swimming pool**—Paint on the bottom of the pool, pool deck, lights

8. Some of the features of the "Smart House" are
   - All the wiring is in one cable instead of several separate lines.
   - All systems are computer controlled.
   - A closed-loop electrical system delivers only when an appliance requires it.
   - Lighting and heating can be controlled by telephone calls.
   - In case of fire, the gas automatically shuts off and the fire department is alerted.
   - Computer controls make the house more energy efficient and convenient.

Assignment Sheet 1 in the Optional Activities Module—Answers will vary. Student performance should be evaluated according to the criteria listed on the assignment sheet.

Exploring Construction Technology

Written Test

Name ______________________________ Score ______________

1. Define the term *system.* Write your answer on the blanks provided beside the term below.

   System ____

   ____

   ____

2. Define the term *construction system.* Write your answer on the blanks provided beside the term below.

   Construction system ____

   ____

3. Define the term *construction technology.* Write your answer on the blanks provided beside the term below.

   Construction technology ____

   ____

4. Define the stages in a basic technology systems model. Write your answers on the blanks provided beside each of the stages below.

   a. **Stage 1: Input** ____

   ____

   ____

   b. **Stage 2: Process** ____

   ____

   ____

   c. **Stage 3: Output** ____

   ____

   ____

   d. **Stage 4: Feedback** ____

   ____

   ____

Written Test

5. Define the types of construction. Write your answers on the blanks provided beside each of the terms below.

   a. **Residential** ______________________________

   ____

   ____

   b. **Civil** ______________________________

   ____

   ____

   c. **Commercial** ______________________________

   ____

   ____

6. Define the major structural systems in a structure. Write your answers on the blanks provided beside each of the terms below.

   a. **Substructure** ______________________________

   ____

   b. **Superstructure** ______________________________

   ____

7. Define the stages in constructing a structure. Write your answer on the blank provided beside each of the stages below.

   a. **Stage 1:** ______________________________

   b. **Stage 2:** ______________________________

   c. **Stage 3:** ______________________________

8. List six of the common types of building materials. Write your answers on the blanks provided below.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

Written Test

9. List five of the emerging construction technologies. Write your answers on the blanks provided below.

a. ____

b. ____

c. ____

d. ____

e. ____

Permission to duplicate this test is granted.

Exploring Construction Technology

Answers to Written Test

1. Group of people, procedures, equipment, and resources that function together to produce desired results

2. System in which manufactured goods and materials are used to build a structure on site

3. Development of more efficient processes and materials to produce better structures on site

4. a. The means by which or the point at which something is put into a system

   b. A series of actions or operations occurring in a system

   c. Something produced by a system

   d. The return to the input stage with evaluative or corrective information about the system processes and output

5. a. Construction that produces structures people live in, such as single-family homes, apartments, and condominiums, and also small commercial buildings

   b. Construction that produces structures built to service the needs of all citizens (other than for shelter or residence), such as dams, bridges, railroads, pipelines, highways, electrical utilities, and water and sewer systems

   c. Construction that produces large structures built to service the needs of business, industry, education, and institutions

6. a. Foundation that supports the upper portion (superstructure) of a structure

   b. Any portion of a structure that rests upon the foundation (substructure)

7. a. Designing and planning the structure

   b. Building the structural systems

   c. Finishing the structure

8. Answers should include any six of the following.

   - Wood products
   - Steel products
   - Concrete products
   - Construction masonry products
   - Construction fasteners
   - Glazing products
   - Thermal-insulation materials
   - Damp-proofing and drainage materials

Answers to Written Test

9. Answers should include any five of the following.

    - Computer-aided design (CAD)
    - New types of building materials
    - Modular construction
    - Prefabricated units
    - "Smart" buildings
    - In-space construction

Exploring Construction Technology

Unit Evaluation Form

Student name ______________________ Unit rating __________

Assignment-sheet ratings

Assignment Sheet 1—Research a Construction Career Rating ______

Comments: ____

____

Assignment Sheet 2—Identify Examples of the Types of Construction in Your Local Area Rating ______

Comments: ____

____

Assignment Sheet 3—Practice Drawing Common Building-Material Symbols Rating ______

Comments: ____

____

Assignment Sheet 4—Interpret a Working Drawing Rating ______

Comments: ____

____

Assignment Sheet 5—Evaluate a Structure Rating ______

Comments: ____

____

Lab-activity sheet ratings

Lab Activity Sheet 1—Design, Build, Test, and Evaluate a Model Substructure Rating ______

Comments: ____

____

Continue to back of this page.

Unit Evaluation Form

Lab Activity Sheet 2—Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure

Rating ________

Comments: ____

____

Lab Activity Sheet 3—Design and Build a Model Modular Structure

Rating ________

Comments: ____

____

List optional assignments and ratings.

Written-test scores

Pretest ________ Posttest ________ Other ________

Comments: ____

____

Teacher signature ______________________ Date ______________

Student signature ______________________ Date ______________

Permission to duplicate this form is granted.

Exploring TECHNOLOGY EDUCATION

Exploring

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Exploring Technology Education:

Exploring Construction Technology

Student Edition

Written by

John D. Joerschke, Technical Writer

Project coordinated by

Sue Jones, Curriculum Specialist
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

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Exploring Construction Technology

Student Edition

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Exploring Construction Technology

Objective Sheet

Unit objective

After completing this unit, the student should be able to define the stages in a basic technology systems model and design, build, and evaluate simple construction projects. The student should demonstrate these competencies by completing the assignment sheets and lab activity sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. Define the term *system.*
2. Define the term *construction system.*
3. Define the term *construction technology.*
4. Define the stages in a basic technology systems model.
5. Define the types of construction.
6. Define the major structural systems in a structure.
7. Define the stages in constructing a structure.
8. List common types of building materials.
9. List some of the emerging construction technologies.
10. Research a construction career. (Assignment Sheet 1)
11. Identify examples of the types of construction in your local area. (Assignment Sheet 2)
12. Practice drawing common building-material symbols. (Assignment Sheet 3)
13. Interpret a working drawing. (Assignment Sheet 4)
14. Evaluate a structure. (Assignment Sheet 5)
15. Design, build, test, and evaluate a model substructure. (Lab Activity Sheet 1)
16. Design, build, test, and evaluate a model truss-bridge superstructure. (Lab Activity Sheet 2)
17. Design and build a model modular structure. (Lab Activity Sheet 3)

Exploring Construction Technology

Information Sheet

1. **Definition of the term *system***

   - **System**—Group of people, procedures, equipment, and resources that function together to produce desired results

2. **Definition of the term *construction system***

   - **Construction system**—System in which manufactured goods and materials are used to build a structure on site

   Note: A *structure* is something made up of a number of parts that are held or put together in a particular way—a constructed product. A *site* is the place where a structure will be or has been built.

3. **Definition of the term *construction technology***

   - **Construction technology**—Development of more efficient processes and materials to produce better structures on site

4. **Stages in a basic technology systems model and their definitions**

   Note: A *systems model* is a visual representation that analyzes the stages (input, process, output, and feedback) in a technology system (see Figure 1 on the next page).

   - **Stage 1: Input**—The means by which or the point at which something is put into a system

     Note: Some of the *inputs* in a construction system are people's skills and knowledge; blueprints or plans; building materials (wood, concrete, steel, masonry products, etc.); energy sources; capital; and tools and machines (see Figure 2 on the next page).

   - **Stage 2: Process**—A series of actions or operations occurring in a system

     Note: Some of the *processes* in a construction system include designing and drawing construction plans, preparing the site for construction, and the work of the builders during the construction process (see Figure 2).

   - **Stage 3: Output**—Something produced by a system

     Note: The *output* in a construction system is the completed structure—home, dam, school, highway, space station, etc. (see Figure 2).

   - **Stage 4: Feedback**—The return to the input stage with evaluative or corrective information about the system processes and output

     Note: Forms of feedback in a construction system are provided by things such as tests and inspections, the response of the people who use the structure, the environmental impact of the structure, and the need for service and repair of the structure (see Figure 2).

Information Sheet

Figure 1: Universal systems model

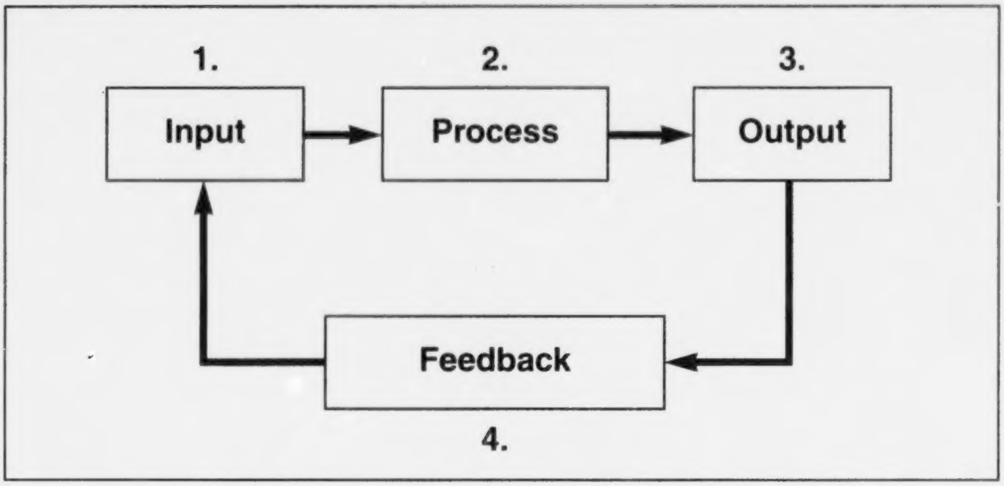
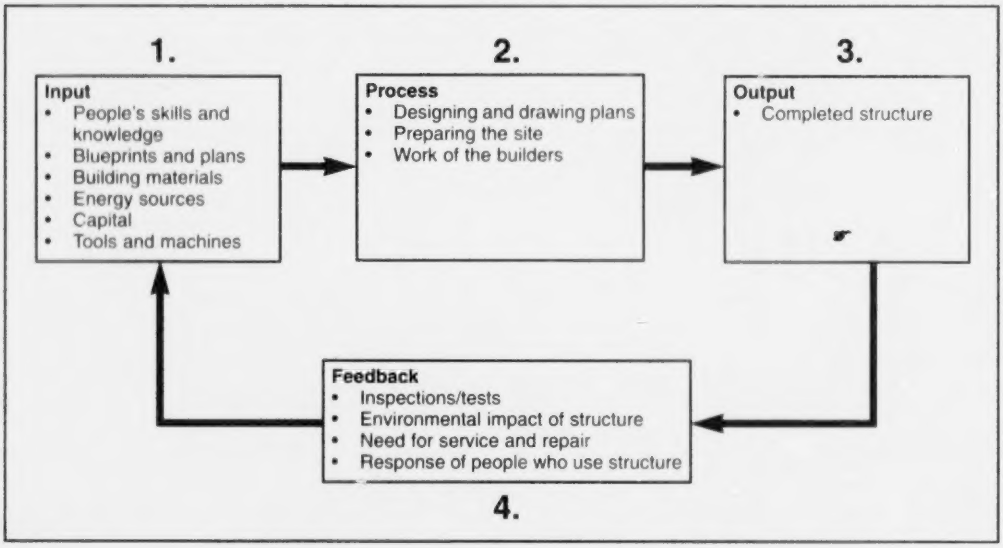

1.
2.
3.
Input
Process
Output
Feedback
4.

Figure 2: Universal systems model showing some of the resources used in the various stages of a basic construction system


1.
2.
3.
Input
• People's skills and knowledge
• Blueprints and plans
• Building materials
• Energy sources
• Capital
• Tools and machines
Process
• Designing and drawing plans
• Preparing the site
• Work of the builders
Output
• Completed structure
Feedback
• Inspections/tests
• Environmental impact of structure
• Need for service and repair
• Response of people who use structure
4.

5. Types of construction and their definitions

- **Residential**—Construction that produces structures people live in, such as single-family homes, apartments, and condominiums, and also small commercial buildings

  Note: Residential construction is primarily wood-frame construction and, therefore, is sometimes referred to as *light construction*. Small commercial buildings are considered light construction and are, therefore, also included in this construction type.

Information Sheet

- **Civil**—Construction that produces structures built to service the needs of all citizens (other than for shelter or residence), such as dams, bridges, railroads, pipelines, highways, electrical utilities, and water and sewer systems

  Note: Civil construction often involves the use of materials such as gravel, earth, sand, steel, and glass and is sometimes referred to as *heavy construction*.

- **Commercial**—Construction that produces large structures built to service the needs of business, industry, education, and institutions

6. **Major structural systems in a structure and their definitions**

Note: A structural system is the weight-bearing frame of a structure. Regardless of its size or complexity, every structure is comprised of two major structural systems—a substructure and a superstructure.

- **Substructure**—Foundation that supports the upper portion (superstructure) of a structure

  Note: Substructures can be made of various materials (concrete, wood, steel) and, in an on-earth structure, are usually constructed below ground.

- **Superstructure**—Any portion of a structure that rests upon the foundation (substructure)

7. **Stages in constructing a structure**

- **Stage 1: Designing and planning the structure**

  Note: In this stage of the construction process, the purpose of the structure, the needs of the people who will use the structure, and the site of the structure are studied, and then designs and plans for the structure are drawn to meet those findings while also considering cost factors and the environmental impact of the future structure.

- **Stage 2: Building the structural systems**

  Note: In this stage of an on-earth construction process, the site is surveyed and excavated (prepared for construction), and then the substructure and superstructure are completed.

- **Stage 3: Finishing the structure**

  Note: Finishing the structure involves roughing in the mechanical systems (electricity, heat and air, and plumbing systems); enclosing the external and internal portions of the structure and adding insulation, soundproofing, and glass; applying finish surfaces (flooring, wall finishes, ceilings); installing lights and plumbing fixtures; and for on-earth structures, landscaping the site.

8. **Common types of building materials**

- **Wood products**

  Examples: Lumber, plywood, glue-laminated timber

  Note: Wood is the material most used in on-earth construction because it is extremely strong yet light and easily shaped and worked. Wood is also readily recyclable and biodegradable, and it is our only renewable building material.

Information Sheet

- **Steel products**

  Examples: Structural steel shapes, open-web steel joists, reinforcing bars, gage steel, welded wire fabric

- **Concrete products**

- **Construction masonry products**

  Note: Masonry products consist of bricks, stones, concrete blocks, and clay-tile products. In use for thousands of years (stone being the oldest natural building material and brick the oldest manufactured material), masonry products are used as building materials because of their durability, beauty, and endless selection of colors and textures.

- **Construction fasteners**

  Examples: Nails, screws, bolts, welds

- **Glazing products**

  Examples: Tempered glass, laminated glass, wired glass, insulated glass, pattern glass, tinted glass, plastic

- **Thermal-insulation materials**

  Note: Insulating materials include any of a number of materials that are used in building construction (batt, loose-fill, rigid-sheet) to reduce heat loss and gain. Insulating materials are all assigned a heat-resistance value (R-value). The higher the R-value, the better the material is as a thermal insulator.

- **Damp-proofing and drainage materials**

  Examples: Damp-proofing materials—polyethylene sheeting, damp-proof coatings, bentonite clay, liquid/water repellant

  Drainage materials—Perforated drainpipe, drainage panel

9. **Some of the emerging construction technologies**

- **Computer-aided design** (CAD)

  Note: In computer-aided design, computers are used by engineers and drafters to produce and store the drawings they create in the design stage of the construction process.

- **New types of materials**

  Note: Technological advances in engineering and manufacturing processes have permitted the development of a whole new range of building materials. These new materials include plastics, laminates, and synthetics as well as ultra-light-weight metal materials.

Information Sheet

- **Modular construction**

  Note: In modular construction, large components of a structure—such as entire rooms or entire sections of a structure—are constructed at a factory, delivered to the construction site, and then assembled on site.

- **Prefabricated units**

  Note: Prefabricated units are small components of a structure—such as pre-hung doors, pre-hung windows, cabinets, wall sections, and roof trusses—that are built in a factory, delivered to the construction site, and then assembled on site.

- **"Smart" buildings**

  Note: "Smart" buildings are structures that include computer-controlled, electronically activated components such as appliances, lighting, heating, cooling, and plumbing.

- **In-space construction**

  Note: Engineers and technicians are developing new techniques for planning and constructing structures in space (the orbiting space station, for example) and on other planets (robots building structures on Mars, for example).

ASSIGNMENT SHEET 1

Exploring Construction Technology

Assignment Sheet 1—Research a Construction Career

Name ______________________________ Date ______________

Evaluation criteria **Rating**

Directions have been followed. ______

Research is thorough and accurate. ______

Report is in correct format. ______

Overall rating ______

Evaluator's comments ______________________________

Introduction

In *Introduction to Technology Education*, Unit 5, "Career-Exploration Process," you learned the process for conducting career research. In this assignment sheet, you will use the skills you learned in Unit 5 to conduct research in the construction area.

There are three major areas of construction-technology careers: (1) skilled construction careers, which are also referred to as *trade occupations*, (2) technical careers, and (3) professional careers.

Skilled construction careers include jobs that usually require three to five years apprenticeship or on-the-job training and/or vocational training at a vocational school or community college. Carpenters, brick masons, welders, roofers, drywall installers, painters, floor layers, plumbers, and pipefitters are examples of those who have skilled careers in construction.

Technical careers include jobs that require two to four years of training in a field of specialization such as construction design, planning, expediting, and distributing. Drafters, surveyors, expeditors, and inspectors are examples of those who have technical careers in construction.

Professional careers include jobs that require a person to have a degree from an accredited college or university and to be licensed in the state in which he or she is working. Architects, engineers, and contractors are examples of those who have professional careers in construction.

Assignment Sheet 1

Exercise

Activity checklist Put a checkmark on the blank line before each activity below as you complete it.

_______ 1. Re-read the examples of some of the careers in the construction area that are listed in the introduction to this assignment sheet. You may be able to name other careers in the construction area, also. Select one career you think you would like to explore, and **research that career**. Use the career-exploration process you learned in Unit 5 of *Introduction to Technology Education* in conducting your research.

_______ 2. **Compile the results** of your research, and prepare a **written research paper** to present the information you have compiled. A written research paper should include the following components:

- Title page
- Table of contents
- Introduction
- Body
- Conclusion
- Endnotes/footnotes

_______ 3. **Turn in** your research paper to your instructor for evaluation.

_______ 4. Your instructor will return your research paper with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return your research paper** to your instructor for **final evaluation**.

Exploring Construction Technology

Assignment Sheet 2—Identify Examples of the Types of Construction in Your Local Area

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Structures listed show an understanding of the definitions and examples presented in Objective 5 in the information sheet.	______
Poster completed is neat, attractive, and well organized visually.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Introduction

You can usually easily identify a structure as being an example of one of the three major types of construction if you know the purpose of that particular structure. This assignment sheet asks you to survey your local area to identify several structures, learn their purpose, and then, classify each structure as being an example of either a residential, civil, or commercial structure. By completing the assignment sheet, you should develop a clearer understanding of the types of structures that fall within the definitions presented in Objective 5 in the information sheet.

Exercise

Activity checklist

Put a checkmark on the blank line before each activity below as you complete it.

______ 1. **Read** the definitions of and the notes concerning examples of the three types of construction—residential, civil, and commercial—that are presented in Objective 5 in the information sheet.

______ 2. Survey your local area to identify three structures that you believe are examples of each of the three types of construction. On a separate sheet of paper, **list** the name and address and **describe** the purpose and type of construction of each of **the nine structures** you have selected.

______ 3. **Turn in** your list and your descriptions to your instructor for evaluation.

Assignment Sheet 2

_______ 4. Your instructor will **return your list and descriptions to you** with suggestions for improvement, and will **select** three structures (one structure from each type of construction) that you will photograph.

Photograph each of the three buildings your instructor has selected, and then, use these photographs to **develop a poster** that identifies each building and its address and describes the purpose and type of construction that building is an example of.

_______ 5. **Turn in** your poster to your instructor for evaluation.

_______ 6. Your instructor will return your poster with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return your poster** to your instructor for **final evaluation**.

Exploring Construction Technology

Assignment Sheet 3—Practice Drawing Common Building-Material Symbols

Name ______________________ Date ____________

Evaluation criteria	**Rating**
Directions have been followed.	______
The completed drawing is to-scale, neat, and well organized visually.	______
Correct symbols/linework were used in the drawing.	______
Overall rating	______

Evaluator's comments ______________________

____

____

Introduction This assignment sheet will provide you with a basic understanding of the material symbols drafters use in developing architectural working drawings and their correct drawing construction.

Exercise

Activity checklist Put a checkmark on the blank line before each activity below as you complete it.

______ 1. **Read** Objectives 7 and 8 in the information sheet and Student Supplement 1, "Building-Material Primer," which begins on page 15.

______ 2. Using the guidelines given on the next page and the proper architectural-materials symbols given in Student Supplement 1, **draw a to-scale** wall-section **drawing** similar to the sketch shown in Figure 1 on the next page. Check with your instructor to determine how you should complete your to-scale drawing—manually with pen and paper or with computer-aided drafting (CAD) equipment.

______ 3. **Turn in** your to-scale drawing to your instructor for evaluation.

______ 4. Your instructor will return your to-scale drawing with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return your drawing** to your instructor for **final evaluation**.

Assignment Sheet 3

Guidelines

Scale: ¾" = 1'-0"

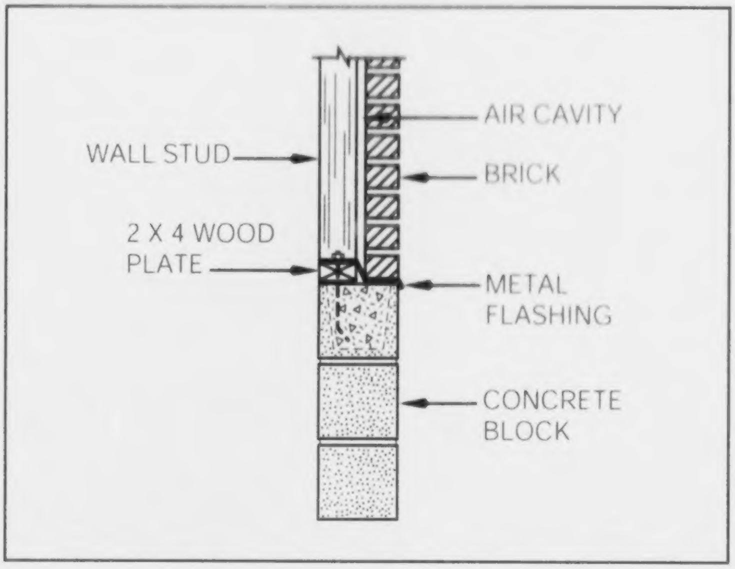
Wood: Nominal 2" x 4" stud

Brick: Modular size

Concrete block: 8" x 8" x 16"

Air cavity: 1" between 2" x 4" wall stud and modular brick

Figure 1: Sketch


AIR CAVITY
WALL STUD
BRICK
2 X 4 WOOD PLATE
METAL FLASHING
CONCRETE BLOCK

Exploring Construction Technology

Student Supplement 1—Building-Material Primer

Introduction

In Objective 8 of the information sheet, you learned that the common types of building materials used in construction today are

- wood products,
- steel products,
- concrete products,
- construction masonry products,
- construction fasteners,
- glazing products,
- thermal-insulation materials, and
- damp-proofing and drainage materials.

A *primer* is "a small introductory book on a subject." The following sections of this student supplement will serve as a primer in which you will learn more about the common types of building materials. Understanding this information will help you in completing Assignment Sheet 3, "Practice Drawing Common Building-Material Symbols," and Assignment Sheet 4, "Interpret a Working Drawing."

Characteristics of lumber used in construction

- **Kind of wood**—Woods are classified as hard or soft, but that classification has more to do with the type of tree the lumber is made from than the actual hardness of the wood. *Hardwood* is produced from any of the groups of trees that have broad leaves. *Softwood* is produced from any of the needle- or cone-bearing trees.

- **Grade**—Lumber is graded based on its strength, appearance, number of defects, and other factors. Methods of grading are outlined by the American Lumber Standards Committee, and then, detailed lists of grades and standards are developed by the various lumber producers' associations, such as the Southern Pine Inspection Bureau, California Redwood Association, Western Wood Products Association, and others. Hardwood grades are regulated by the National Hardwood Lumber Association.

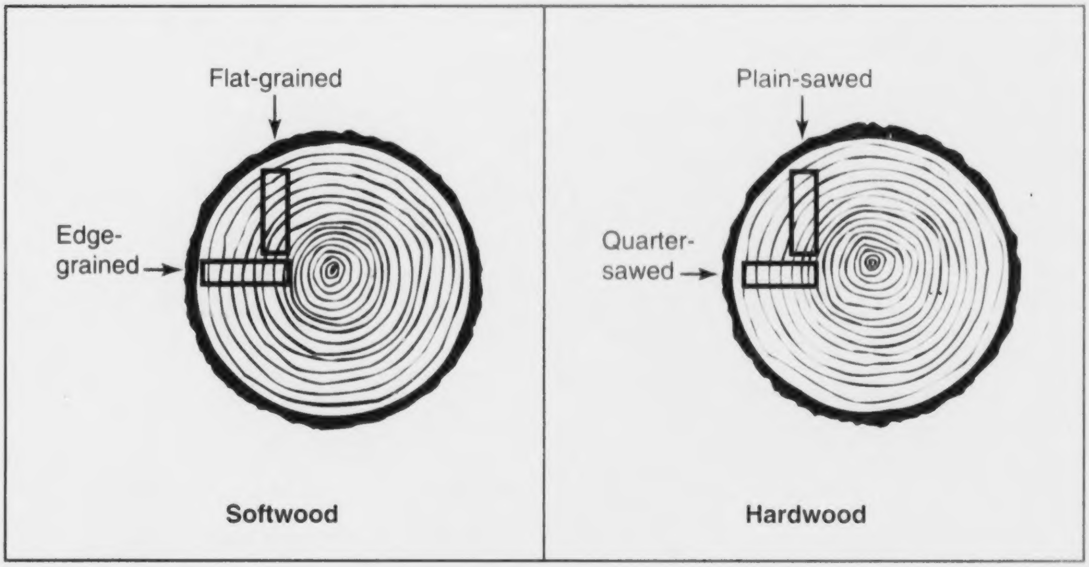
- **Size**—Lumber products come in standard sizes based on width, thickness, and length. Size may be *actual* or *nominal*. Nominal size is the size of the materials before final processing and tends to be larger than the actual size after drying and shaping (see Table 1).

Table 1: Comparison of nominal and actual dimensions of common dimension lumber

Nominal dimensions (in inches)	**Actual dimensions** (in inches)
2 x 4	1½ x 3½
2 x 6	1½ x 5½
2 x 8	1½ x 7¼
2 x 10	1½ x 9¼
2 x 12	1½ x 11¼

- **Sawing method**—Most trees are sawed so that the growth rings form an angle of less than 45 degrees with the surface of the boards produced. Such lumber is called *flat-grained* in softwood or *plain-sawed* in hardwoods. Wood that is cut with the growth rings at an angle greater than 45 degrees is called *edge-grained* in softwoods and *quarter-sawed* in hardwoods (see Figure 1).

Figure 1: Sawing methods



Types of wood products commonly used in construction

- **Dimension lumber**—Solid-wood members 2 to 5 inches thick and 2 inches or more wide
  - **Rough framing members**—Nonsurfaced dimension lumber used as structural and backing supports

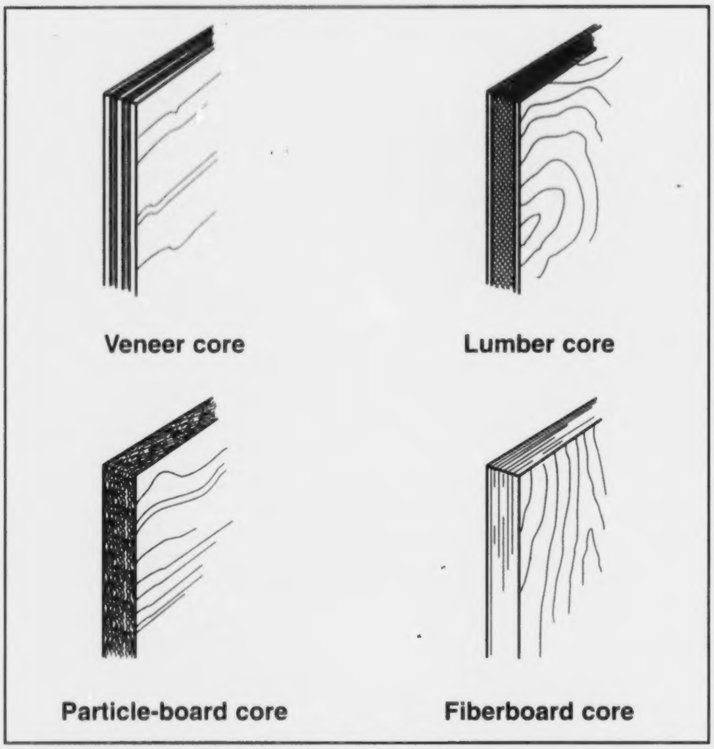
    Rough framing members are lumber with uneven, unfinished surfaces that are later covered by finish materials.
  - **Finished wood trim**—Surfaced dimension lumber that is left exposed at the completion of construction

    Finish material, such as that applied around window and door openings or at the floor and ceilings of rooms, requires a high grade of lumber for a desirable appearance.
- **Plywood panels** (see Figure 2 on the next page)—Fabricated wood products manufactured from an odd number of wood sheets joined with glue

  Standard plywood-sheet size is 4'-0" wide and 8'-0" long. Different thicknesses, core materials, and surface thicknesses are available.

Student Supplement 1

Figure 2: Types of plywood core construction



Veneer core
Lumber core
Particle-board core
Fiberboard core

- **Heavy timbers**—Square-sawn wood members 5 inches or more thick and 5 inches or more wide

  Large timber members are defined normally in relation to the span (in feet) that they support. For example, a timber beam will have an actual depth of approximately one-sixteenth of its span. Heavy timbers have certain advantages over steel or masonry in that they can be cut to nominal dimensions, retain their integrity much longer during fire, and also are more appealing in appearance and finish.

- **Glue-laminated timbers**—Timbers created when two or more strips of wood are glued together to form a single wood member

  Glue-laminated timbers can provide extensive structural support for construction.

Types of steel products commonly used in construction

- **Structural steel shapes** (see Figure 3-a on the next page)—Steel products produced in standard shapes (beams, angles, etc.) and sizes so that architects and engineers will be able to select members for construction that will result in good connections and a minimal waste of steel

  - **American standard beams** (see Figure 3-b)—I-shaped steel members used as both load-carrying horizontal beams and load-carrying vertical columns

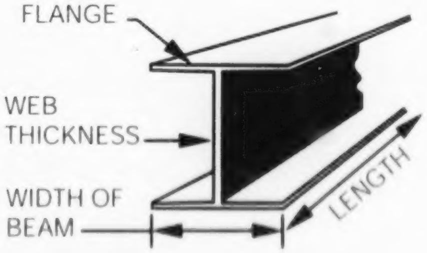
- **Wide-flanged beams** (see Figure 3-c)—H-shaped steel members with wider flanges than American standard beams; used primarily for horizontal beams and vertical columns

  The wider flanges of this type of beam increase the load-carrying capacity of the beam.

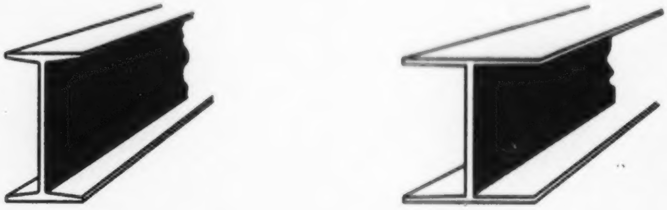
- **Channel steel** (see Figure 3-d)—C-shaped steel members used for bracing, short beams, and lintels

- **Steel angles** (see Figure 3-e)—L-shaped members produced with equal or unequal legs and used as short beams, window and door lintels, diagonal braces, and as connecting members for wide-flanged beams

Figure 3: Structural-steel shapes

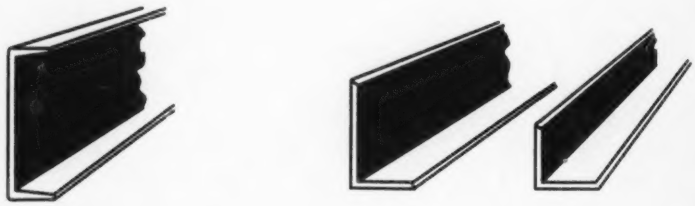


a. **Components of structural-steel shapes**



b. **American standard**

c. **Wide-flanged**



d. **Channel steel**

e. **Steel angles**

Student Supplement 1

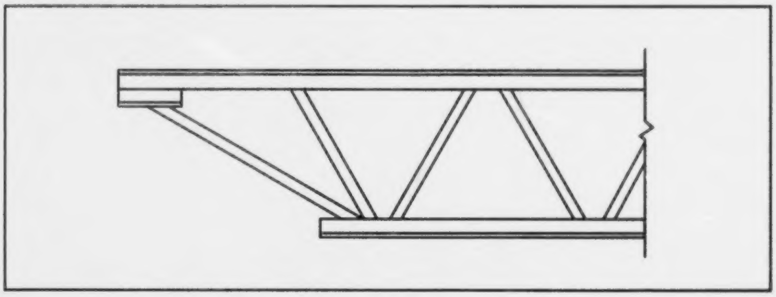
Table 2: Typical designations for structural-steel shapes

Descriptive name	Typical designation	Explanation
American standard beam	S8 x 23	*S* is the symbol identifying an American Standard beam. *8* is the nominal beam depth in inches. *23* is the weight per foot of length in pounds.
Wide-flanged beam	W21 x 142	*W* is the symbol identifying a wide-flanged beam. *21* is the nominal beam depth in inches. *142* is the weight per foot of length in pounds.
Channel steel	C6 x 13	*C* is the symbol identifying channel steel. *6* is the nominal depth in inches. *13* is the weight per foot of length in pounds.
Steel angle—unequal legs	L8 x 6 x ½"	*L* is the symbol identifying steel angle. *8* is the length of the long leg in inches. *6* is the length of the short leg in inches. *½* is the material thickness of the angle in inches.

- **Open-web joists** (see Figure 4)—Mass-produced structural-steel joists (trusses) formed from steel angles and steel rods and used in equally spaced arrays to provide support for floor loads and roof loads

Joists are classified according to the joist depth and the span the joist will carry. Table 3 on the next page shows common joist designations, depths, and spans.

Figure 4: Elevation view of the end of an open-web steel joist



Student Supplement 1

Table 3

Joist designation	**Depth** (in inches)	**Span** (in feet)
J or H	8 to 24	8 to 48
LJ or LH	18 to 48	25 to 96
DLJ or DLH	52 to 72	89 to 144

- **Reinforcing bars** (rebar)—Steel rods produced in various diameters and designed to be embedded in concrete to provide strength in tension
- **Gage steel**—Thin sheets of steel formed into various shapes and used as rigid structural members

  Gage steels are fabricated as wall studs, window and door frames, roof decking, and mechanical ductwork.

- **Welded wire fabric**—Square grids formed of wire fabric and used to provide tension strength when embedded in concrete-slab floors

Definitions of the terms *cement* and *concrete*

- **Cement**—Powder made from alumina, silica, lime, iron oxide, and magnesia burned together in a kiln and finely pulverized; an ingredient in concrete

  During the cement manufacturing process, two types of raw materials—one made primarily from limestone, marl, and shells and another made primarily from clay, shale, silica sand, iron ore, and alumina—are blended, ground, and dried; then clinker and gypsum are added and that mixture is ground again. After the manufacturing process is complete, cement is ground so finely that it will pass through a #200 sieve, which has 40,000 openings per square inch.

- **Concrete**—Building material made by mixing cement, sand and aggregates, admixtures, and water

  The elements listed above are mixed in various ratios depending upon the required strength and application (see Figure 5 on the next page). The concrete is then allowed to set (cure) for approximately 28 days until it reaches nearly full strength.

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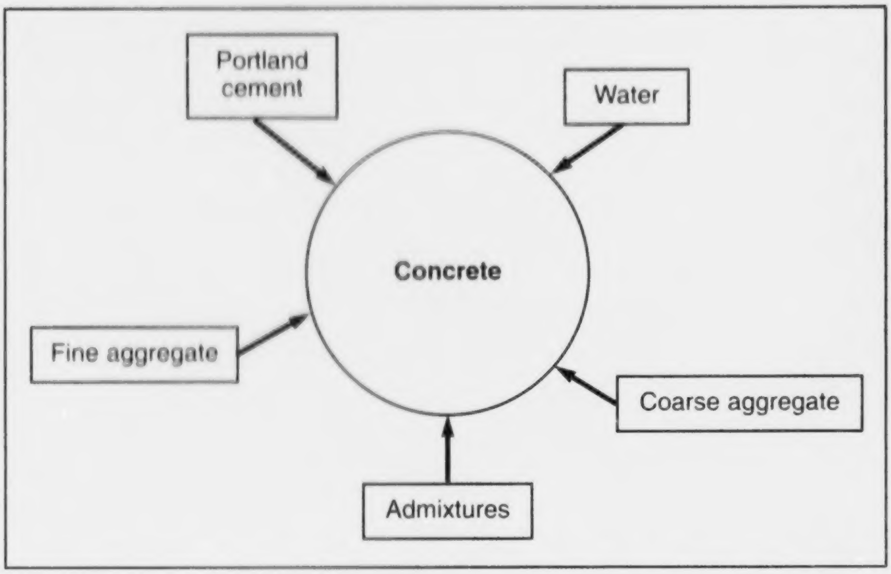
Figure 5: Basic elements of concrete

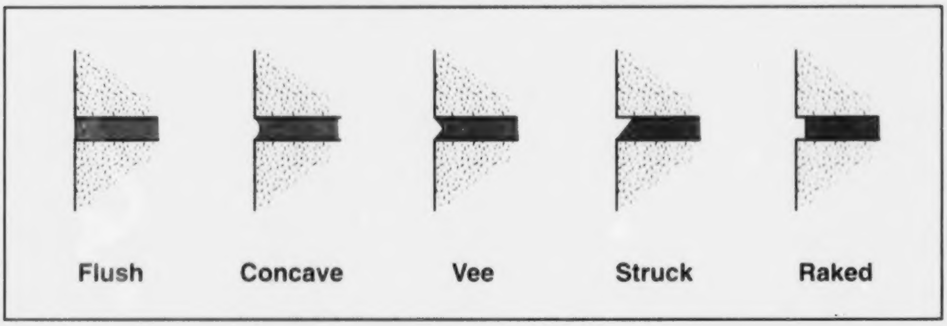

Portland cement
Water
Concrete
Fine aggregate
Coarse aggregate
Admixtures

Types of masonry products commonly used in construction

- **Mortar**—Mixture of fine aggregate and cement paste used to fill voids between aggregate or masonry units and reinforce the structure

  Mortar provides cushioning, acts to seal the units from wind and water, and adheres the units to one another to bond them into a single structural unit. The typical mortar joints are shown in Figure 6 below.

  Figure 6: Typical mortar joints

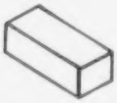

Flush
Concave
Vee
Struck
Raked

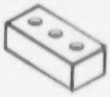
- **Brick**—Rectangular blocks made from clay or clay mixture molded into blocks and then hardened by drying in the sun or baking in a kiln

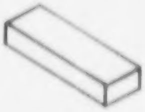
  Brick has two distinct qualities: size and resistance to fire. Its small unit size (see Table 4 on the next page) permits great variation in appearance and design, and brick is the most fire-resistant masonry product available.

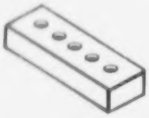
Table 4: Brick types and sizes

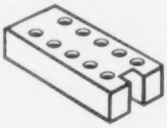
Type	Actual dimensions			Modular dimensions		
	Width	Height	Length	Width	Height	Length
Standard	3¾"	2¼"	8"			
Modular	3½"	2¼"	7½"	4"	2⅔"	8"
Roman	3½"	1½"	11½"	4"	2"	12"
Norman	3½"	2¼"	11½"	4"	2⅔"	12"
SCR	5½"	2¼"	11½"	6"	2⅔"	12"


Standard


Modular


Roman


Norman


SCR

- **Face brick** (facing brick)—Brick finish product manufactured under strictly controlled standards for dimension, color, and structural quality

- **Common brick**—Brick product manufactured under less strictly controlled standards for dimension and color and used for wall backing or other applications where appearance is not important

- **Stone masonry**—Masonry product formed of natural rock

  Used primarily for its decorative appearance, stone masonry can be laid like brick, using mortar, or attached with fasteners in large thin sheets as a facing over a structural frame.

  - **Rubblestone** (rubble, rubble masonry)—Stone-masonry product composed of roughly squared stone with irregular size and shape (see Figure 7-a on the next page)

    Rubblestone construction is composed of irregularly shaped pieces that must be matched to all other pieces for a good fit and is used where a rustic appearance is desired.

  - **Cut stone** (ashlar)—Stone-masonry product composed of squared stone with a flat surface (see Figure 7-b)

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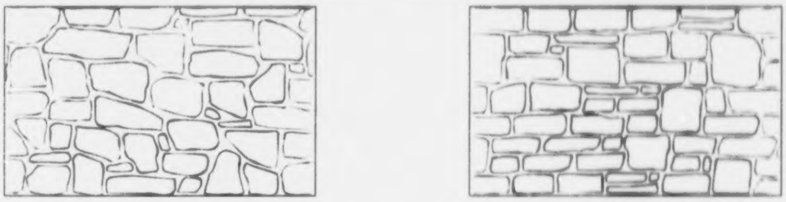
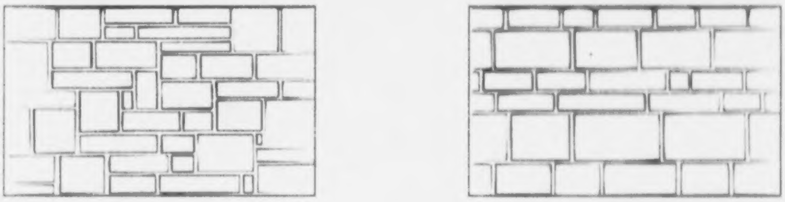
Figure 7: Stone-masonry products



Random rubble

Coursed rubble

a. **Rubblestone**



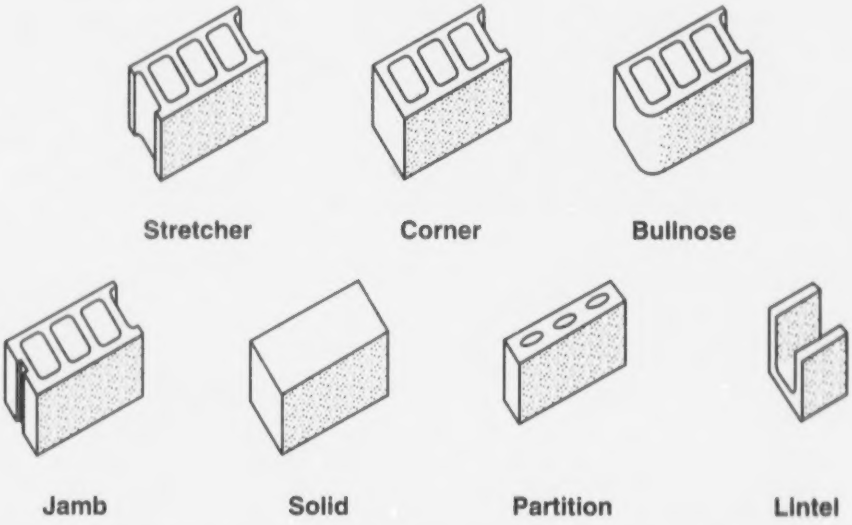
Random ashlar

Coursed ashlar

b. **Cut stone** (ashlar)

- **Concrete block** (see Figure 8)—Concrete-masonry units (CMUs) formed into modular sizes and shapes and used in constructing load-bearing walls, foundation walls, non-load-bearing partitions, and as a backup for other walls

Figure 8: Common CMUs


Stretcher
Corner
Bullnose
Jamb
Solid
Partition
Lintel

- **Clay-tile product**—Fired-clay product used for roofing, drainage pipe, and wall and floor finish material
  - **Structural clay tile**—Hollow or solid building members molded from clay, set in mortar, and used in masonry construction such as non-load-bearing partition walls, backup for walls, and as fireproofing around structural steel
  - **Tile**—Fired-clay product used as a finish material for floors, walls, or roofs

    Tile is set in place using cement, latex adhesive, or epoxy mortar.

Types of fasteners commonly used in construction

- **Nails**—Fasteners consisting of a straight, slender piece of metal with one pointed end and one end that is struck with a hammer or driven with a pneumatic or powder-actuated gun

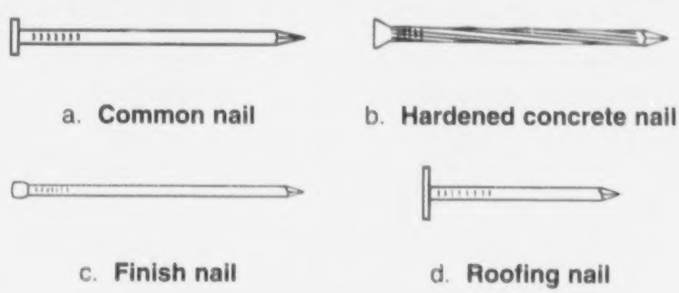
  Nails come in various sizes, finishes, and materials for use in different applications (i.e., roofing, masonry, wood) (see Figure 9-b and 9-d). Common nails and finish nails are the two most common types used.

  - **Common nails** (see Figure 9-a)—Nails with a smooth cylindrical shaft and a flat head

    Common nails are used for light-frame wood construction, roofing, and masonry.
  - **Finish nails** (see Figure 9-c)—Nails with a smooth shaft and a very small barrel-shaped head that creates a small void in the surface of the workpiece

    Finish nails are used for finished woodwork such as cabinetry and other areas where appearance is important.

Figure 9: Common types of nails



a. **Common nail**

b. **Hardened concrete nail**

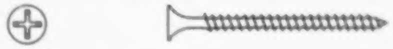
c. **Finish nail**

d. **Roofing nail**

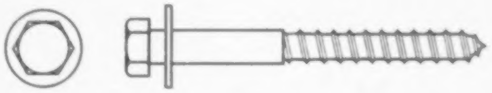
- **Screws**—Wood or metal fasteners consisting of a tapered, threaded shank and a head designed to allow turning of the fastener

  Screws are used where it may be necessary to remove a fastener at a later date for adjustment or remounting. Screws are manufactured with various types of threading depending upon the type of material the screw is to be used with (i.e., wood, metal, sheet metal) (see Figure 10). Screws form stronger connections than nails.

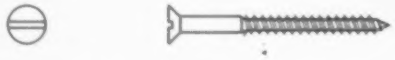
  Figure 10: Common types of screws



Drywall screw with Phillips head



Lag screw with hex head

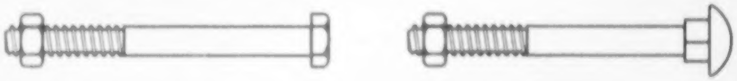


Wood screw with slotted head

- **Bolts** (see Figure 11)—Large cylindrical fasteners usually consisting of a piece of metal having a head or hooked end and a fully or partially threaded body

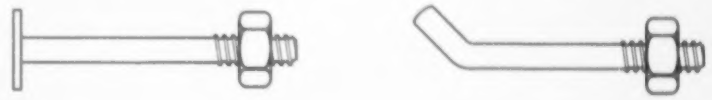
  Bolts are used for heavier structural applications and have nuts that are threaded opposite the head end to secure the connection and prevent the bolt from loosening or backing out.

Figure 11: Common types of bolts used in building construction



Machine bolt

Carriage bolt



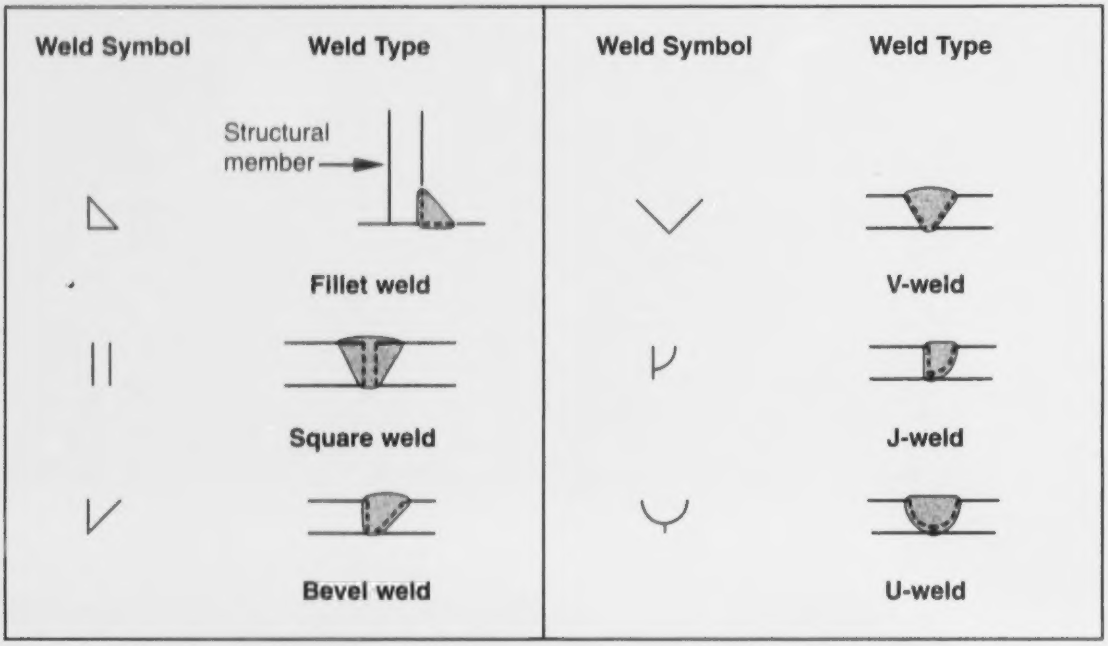
Anchor bolt with welded plate

J-bolt

- **Welds**—Method of using high electrical voltage to create intense heat that then bonds a steel welding rod to structural members to be joined

  The welding process creates a structural connection that is actually stronger than the members themselves. Figure 12 shows common types of welds and their appropriate drawing symbols.

Figure 12: Common welds



Types of glazing products commonly used in construction

- **Sheet glass** (window glass)—Clear or opaque glass material manufactured in continuous, long, flat pieces and cut to desired sizes and shapes

  Sheet glass is manufactured in single strength (3⁄32" to ⅛") and double strength (⅛" to ⅞"). It is used primarily in low buildings with relatively small windows.

- **Tempered glass**—Glass manufactured by reheating and then rapidly cooling cut glass, resulting in a glass that is much more resistant to thermal stress and impact

  Tempered glass is used for windows exposed to heavy wind pressures or to intense heat and cold and for doors and windows next to doors.

- **Laminated glass**—Glass manufactured by bonding transparent vinyl between layers of sheet glass, resulting in a safety glass that adheres to the vinyl if broken

  Laminated glass is used in public areas, overhead, and in large exposed facilities, providing a large degree of safety to people.

Student Supplement 1

- **Wired glass** (wire glass)—Glass in which wire mesh is embedded between two layers of sheet glass, resulting in a safety glass that prevents the glass from shattering if broken

  Wired glass is used for windows in fire doors and fire walls because it maintains its integrity as a fire barrier much longer than any other glass product.

- **Insulated glass**—Glass manufactured by separating layers of sheet glass with a ⅛- to 1-inch air space that is then sealed

  Insulated glass is used in buildings where insulation factors are important.

- **Pattern glass**—Glass produced with different surface designs that obscure vision but allow light transmission

  Pattern glass is used where privacy is an important factor.

- **Tinted glass**—Colored glass produced by adding small amounts of chemical elements to the molten glass mixture

  Tinted glass is used in windows to achieve a desired appearance as well as to control light and heat transmission into a building's interior.

- **Plastic**—Glazing product manufactured from clear or opaque synthetic materials

  Plastics are in common use today to help control the costs of glazing materials and to provide an added measure of safety.

Types of thermal-insulation materials commonly used in construction

- **Batt insulation** (blanket insulation)—Insulating material usually composed of fiberglass, rock-wool, or cellulose material with or without a thin facing material, and made in relatively small units for convenience in handling and applying

  Sizes of batt insulation vary from 3 to 7 inches or more in thickness, and from 15 to 23 inches in width. They are usually 48 inches in length. Facing materials may be kraft paper, metal foil, or plastic sheets.

- **Loose-fill insulation**—Insulating material manufactured as small granules or particles that are poured or blown into voids in floors, walls, or roofs

  Some of the more-common materials used in loose-fill insulation are cellulose, perlite, fiberglass, and vermiculite.

- **Rigid-sheet insulation**—Insulating material manufactured in stiff sheets designed to be nailed or glued to the surface to be insulated

  Rigid-sheet insulation is produced in 2′ x 8′ or 4′ x 8′ sizes, comes in varying thicknesses, and is usually made from polystyrene or urethane-foam materials

Thermal-insulation applications

Applications for thermal insulation are commonly described by the area in the building where the insulation will be located (i.e., floor, wall)

- **Ceiling insulation**—Batt or loose-fill insulation placed above the ceiling framing to provide resistance to heat conduction into the area above the ceiling

- **Floor insulation**—Batt or rigid-sheet insulation placed below the floor framing to provide resistance to heat conduction into the crawl-space area

- **Perimeter insulation**—Batt or rigid-sheet insulation installed over a building's concrete foundation wall

- **Wall insulation**—Any of the various types of thermal insulation placed between structural wall members to provide resistance to heat conduction in and out of the building

- **Duct insulation**—Insulation wrapped around heating and cooling ductwork to reduce heat or cooling loss from the ducts

- **Slab insulation**—Rigid-sheet insulation placed below a concrete slab to provide resistance to heat conduction from the concrete slab

Types of damp-proofing and drainage materials commonly used in construction

The portion of a building below the ground (finished grade line) is subject to groundwater penetration. The two fundamental ways to address this major problem are through the proper use of damp-proofing materials and drainage systems.

- **Damp-proofing materials**—Materials that prevent the flow of groundwater into structural members

  - **Polyethylene sheeting**—Flexible plastic sheets placed between concrete-slab floors and grade to act as a vapor barrier to prevent the groundwater from penetrating upward into the slab floor

  - **Damp-proof coatings**—Asphalt-based liquid brushed or sprayed onto foundation walls to seal the concrete and prevent groundwater penetration into the foundation

  - **Bentonite-clay sheets**—Corrugated cardboard sheets with internal cells filled with dry bentonite clay; when applied to foundation walls and then saturated with water, the sheets expand and form a continuous nonporous membrane over the foundation walls

  - **Water repellant**—Liquid brushed on wood and other porous materials to prevent water penetration

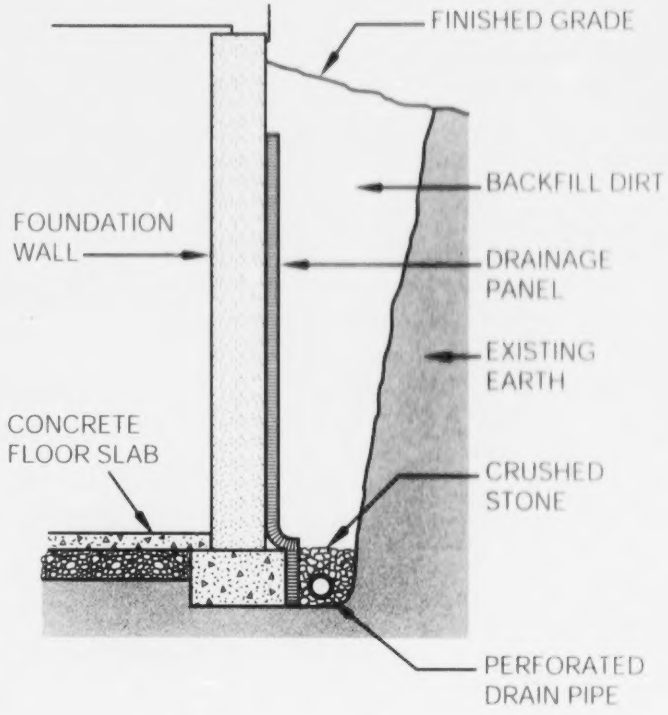
- **Drainage-system materials**—Pipes and panels used with channels or trenches to convey groundwater away from a structure

  Drainage materials are extremely important in preventing groundwater buildup (hydrostatic pressure) against foundation walls and concrete floor slabs (see Figure 13 on the next page).

- **Perforated drain pipe**—Pipe with a series of holes; the pipe is placed outside the foundation walls at the footing to channel groundwater away from the structure by gravity (see Figure 13)
- **Drainage panel**—Panel constructed of an open porous material with a fabric filter exterior; when a panel is attached to the foundation walls, the fabric filter allows groundwater to enter the panel, where it is channeled downward and emptied into a drainage pipe (see Figure 13)

  In some areas of the country, drainage fill will be used in place of a drainage panel.

Figure 13: Drainage system


FINISHED GRADE
BACKFILL DIRT
FOUNDATION WALL
DRAINAGE PANEL
EXISTING EARTH
CONCRETE FLOOR SLAB
CRUSHED STONE
PERFORATED DRAIN PIPE

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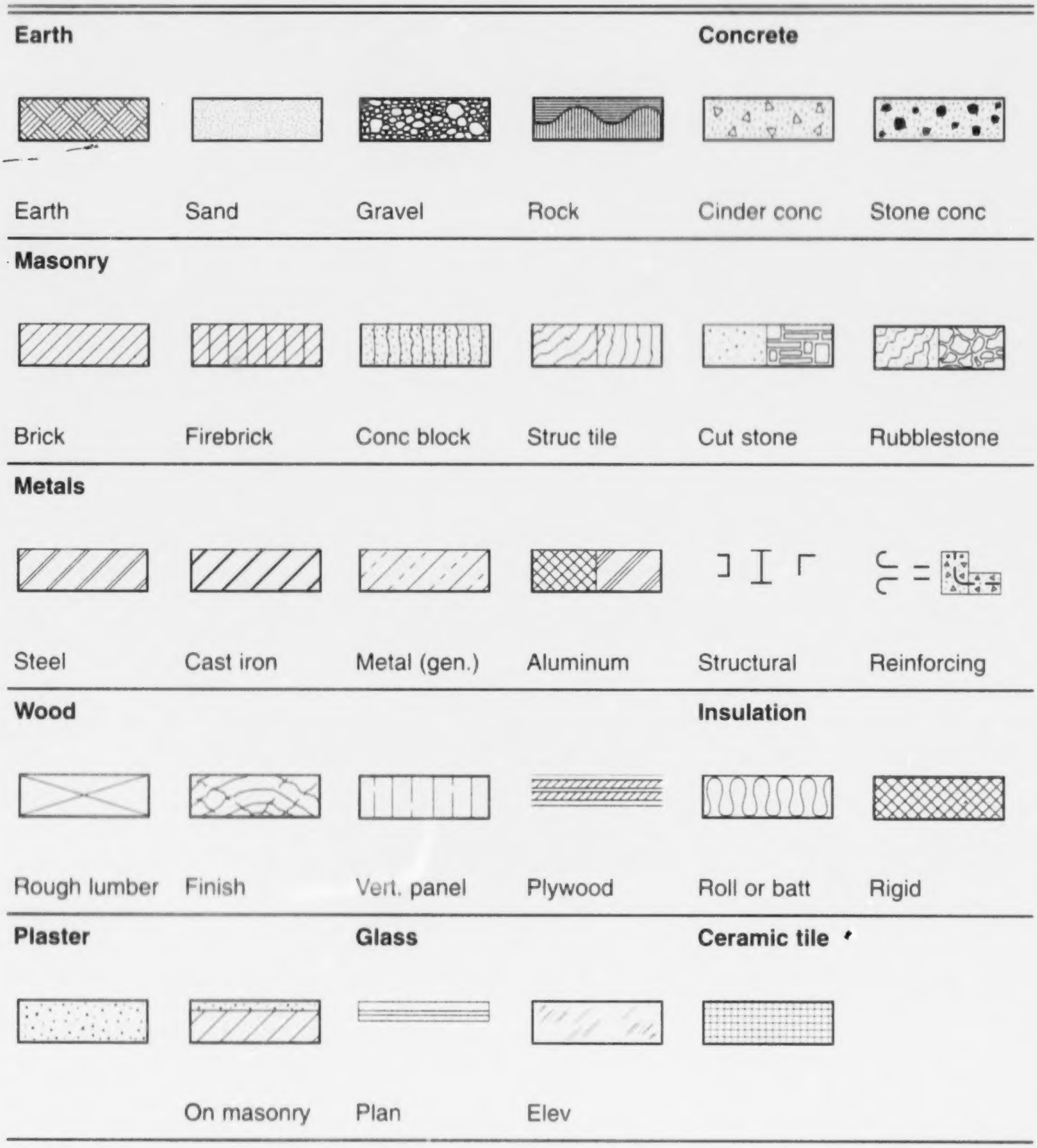
Student Supplement 1

Common construction-material symbols used on architectural drawings

The symbols shown in Table 5 are those used on section drawings. Symbols are often modified on other types of drawings, such as foundation plans and elevation drawings. Also, the symbols shown are for the materials most commonly used as architectural building materials.

Table 5: Common construction-material symbols

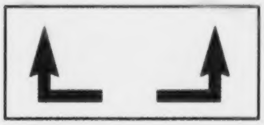

Earth
Concrete
Earth
Sand
Gravel
Rock
Cinder conc
Stone conc
Masonry
Brick
Firebrick
Conc block
Struc tile
Cut stone
Rubblestone
Metals
Steel
Cast iron
Metal (gen.)
Aluminum
Structural
Reinforcing
Wood
Insulation
Rough lumber
Finish
Vert. panel
Plywood
Roll or batt
Rigid
Plaster
Glass
Ceramic tile
On masonry
Plan
Elev

Student Supplement 1

Terms and definitions associated with linework techniques

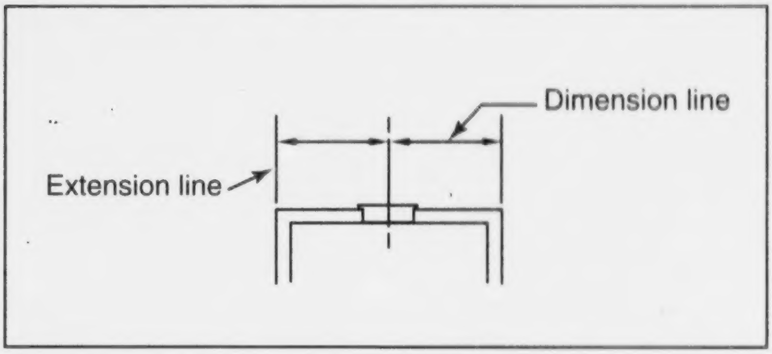
- **Cutting-plane line** (see Figure 14)—Heavy broken line indicating the plane at which a cross section is taken and the direction of viewing the object

  Figure 14



- **Dimension line** (see Figure 15)—Line indicating the dimension of a part or member

  Figure 15



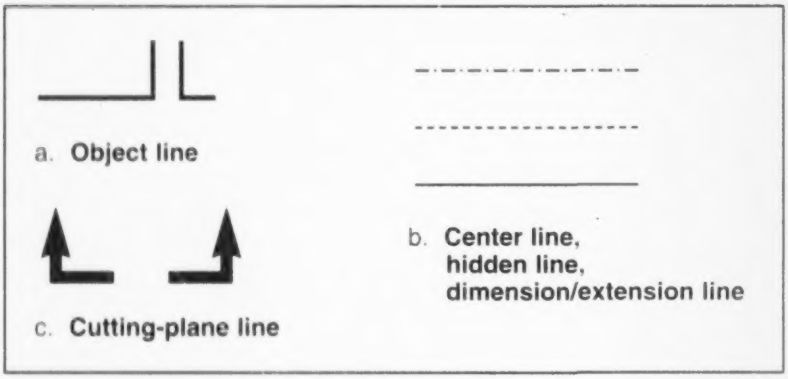
- **Extension line** (see Figure 15)—Line extending from an object line to a dimension line
- **Line intersection**—Point where two lines meet

Standard architectural-linework techniques

Architectural drafting employs linework techniques that allow for clarity and readability of the complex drawings produced. Proper use of these preferred linework techniques is essential for producing quality architectural drawings.

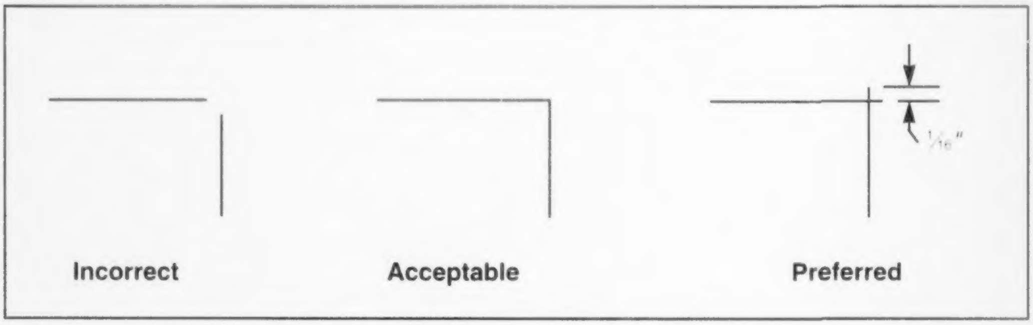
- **Line-weight contrast**
  - Object lines are drawn as heavy lines to create a silhouette of the object being drawn (see Figure 16-a on the next page)
  - Center lines, extension lines, hidden lines, and dimension lines are drawn as thin lines so as not to blend in with or overpower the object lines (see Figure 16-b)
  - Cutting-plane lines are drawn as extremely heavy lines that allow for quick identification (see Figure 16-c)

Figure 16


a. Object line
b. Center line,
hidden line,
dimension/extension line
c. Cutting-plane line

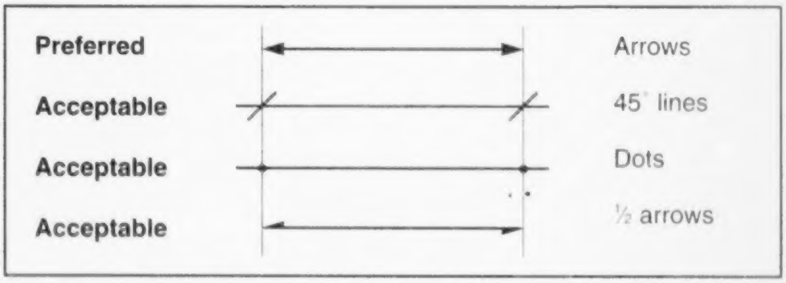
- **Line intersections** (see Figure 17)—Intersecting lines are extended approximately 1/16 inch beyond one another

Figure 17


1/16"
Incorrect
Acceptable
Preferred

- **Arrowheads** (see Figure 18)—Four types of arrowheads are permitted on architectural drawings; however, a drafter should show consistency in using the arrowhead type chosen

Figure 18


Preferred
Arrows
Acceptable
45° lines
Acceptable
Dots
Acceptable
½ arrows

Exploring Construction Technology

Assignment Sheet 4—Interpret a Working Drawing

Name ______________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Answers to the analysis check are relevant, well thought out, and show an understanding of the material presented in Student Supplement 2.	______
Overall rating	______

Evaluator's comments ______________________________

Introduction

Every structure begins as an idea, and before construction can begin to turn that idea into a reality, the construction process must be carefully planned. Construction planning begins with a complete set of working drawings.

The ability to read and interpret working plans, then, is a basic skill to a successful career in the construction area. This assignment sheet asks you to learn about working drawings and then interpret a very basic drawing, and thereby, you gain an understanding of the role that working drawings play in planning the construction process.

Exercise

Activity checklist

Put a checkmark on the blank line before each activity below as you complete it.

______ 1. **Review** Objectives 7 and 8 in the information sheet, and Student Supplement 1. Then, **read** Student Supplement 2, "Introduction to Working Drawings," which begins on page 37.

______ 2. Study the basic working drawing presented in Figure 1 on page 35.

______ 3. On a separate sheet(s) of paper, **answer the questions in the Analysis Check** on page 34.

______ 4. **Turn in your answers** to the analysis check to your instructor.

______ 5. Your instructor will return your answers to the analysis check with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return** your answers to your instructor for **final evaluation**.

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Assignment Sheet 4

Analysis Check

1. What type of working drawing is shown in Figure 1?
2. What is the overall measurement of the building?
3. What is the thickness of the walls in the building?
4. List the names of the four rooms that will be constructed within the building.
5. What is the measurement of the break room?
6. How many exterior doors will be needed to complete the building?
7. How many interior doors will be needed to complete the building?
8. How many windows will be needed on the south wall of the building?
9. How many windows will be needed on the west wall of the building?
10. Two-by-four studs will be used in framing the walls within the building. Two-by-four studs are normally spaced 16 inches apart. However, to estimate the number of studs that will be required for a building, it is customary to allow one stud for every one foot of wall.

    Knowing these facts, estimate how many studs will be needed to frame the following rooms. Round your answers up for ½ foot or more.

    a. How many studs will be needed for the exterior walls of the building?

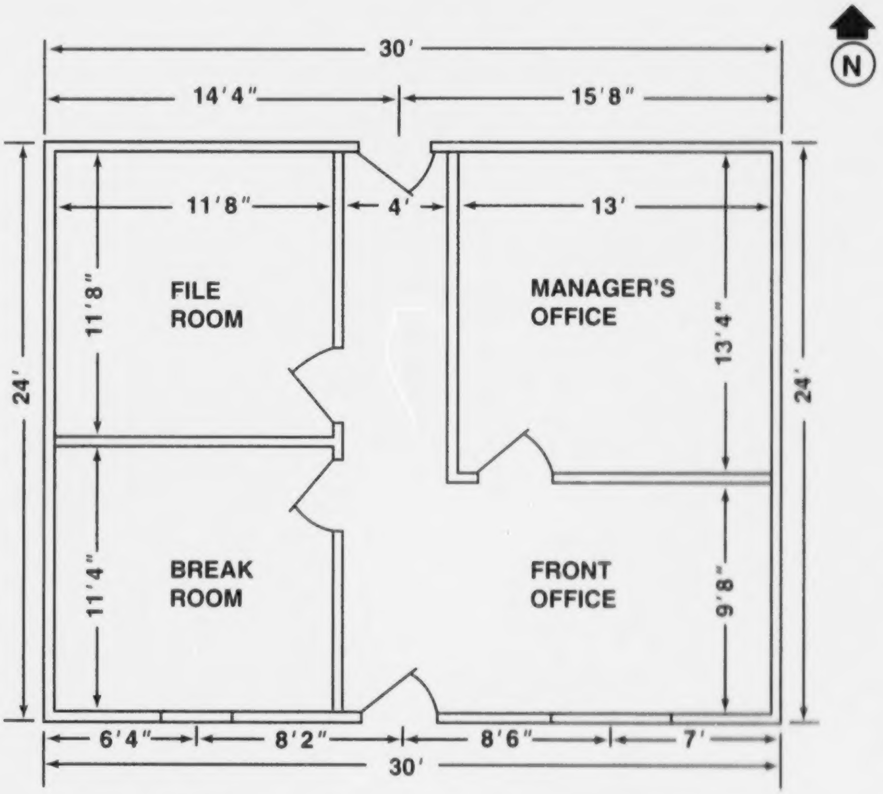
    b. How many studs will be needed for the four walls of the manager's office?

    c. How many studs will be needed for the four walls of the file room?

    d. If each stud costs $ .75, what will be the total cost of the studs required for the exterior walls of the building, the manager's office, and the file room?

Assignment Sheet 4

Figure 1: Working drawing


N
30'
14'4"
15'8"
11'8"
4'
13'
FILE ROOM
MANAGER'S OFFICE
11'8"
13'4"
24'
24'
BREAK ROOM
FRONT OFFICE
11'4"
9'8"
6'4"
8'2"
8'6"
7'
30'

NOTE: ALL WALLS ARE 4" THICK.
ALL EXTERIOR DOORS ARE 3' WIDE.

MAVCC CONSTRUCTION		
MURRAY OFFICE BUILDING		
SCALE 1/4" = 1'	DRAWN BY AM	SHEET A1 OF 4 SHEETS

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Exploring Construction Technology

Student Supplement 2—Introduction to Working Drawings

Introduction

In Objective 7 of the information sheet, you learned that designing and planning a structure is the first stage in the construction process and that the working drawings for the structure are completed during this stage.

In the introduction to Assignment Sheet 4, you also learned that being able to interpret these drawings is a basic skill necessarily learned by the workers in every stage of the construction process.

Understanding the information presented in Student Supplement 1 and in this student supplement, then, will help you learn the basic construction skill of interpreting working drawings.

Terms and definitions

- **Working drawings**—Set of detailed drawings or plans drawn to scale by a drafter; shows all the information and dimensions necessary to build or remodel a structure

  Working drawings consist of several different kinds of drawings, usually assembled into a set: plot plan, foundation plan; floor plan(s); elevation drawings; section drawing(s); detail drawings; electrical drawings; and mechanical drawings that include heating, ventilation, and air conditioning (HVAC) drawings and plumbing drawings. The set may also include finish schedules, a presentation drawing, and a structural drawing.

- **Mechanical drawing**—Drawing showing location and details about plumbing components and heating and air-conditioning units

  Mechanical features may be drawn on the basic floor or foundation plan, or may be shown in separate drawings.

- **Schedule**—Listing or chart of parts (keyed to the plans), amounts, materials or products, and details (see Figure 1 on the next page)

  Schedules may appear on the same page as a plan or on a separate page in the set of plans. Schedules may be listed for windows, doors, room finishes, paint, appliances, fixtures, lintels, headers, and reinforcing steel. Figure 1 shows sample schedules for doors and windows.

Student Supplement 2

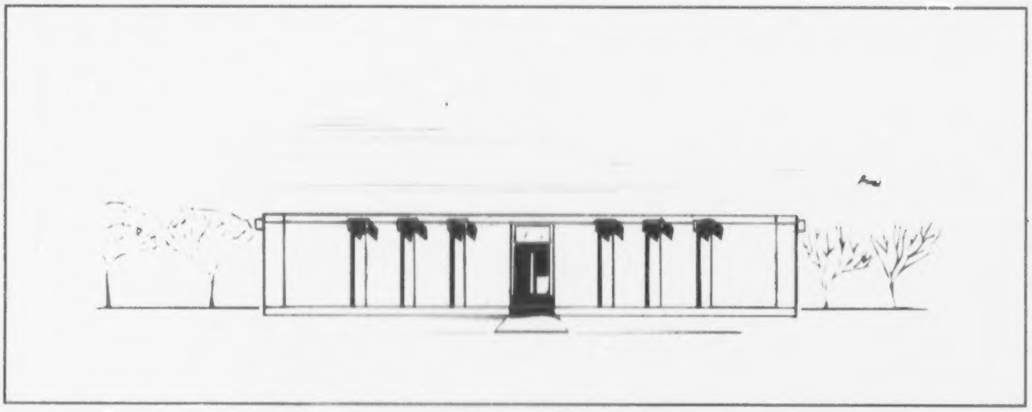
Figure 1: Sample schedules

Door Schedule			
Mark	Size	Amt Req'd	Remarks
A	5'-0" x 6'-8" x 1¾"	1	Exterior flush door
B	2'-8" x 6'-8" x 1¾"	7	Flush doors 1-Sliding 1-Metal clad
C	2'-6" x 6'-8" x 1⅜"	4	Flush door
C_1	2'-6" x 6'-8" x 1⅜"	2	Louvered
D	2'-4" x 6'-8" x 1⅜"	4	Flush door
D_1	2'-4" x 6'-8" x 1⅜"	1	Louvered
E	1'-3" x 6'-8" x 1⅜"	1	Bifold louvered
F	2'-10" x 6'-8" x 1¾"	2	Exterior 2 lights
G	2'-8" x 6'-8" x 1¾"	1	Exterior 2 lights

Window Schedule		
Mark	Size	Remarks
A	(2) 3'-0" x 4'-2"	DH see specs
B	(2) 3'-0" x 3'-2"	"
C	—	Trimline Bay 53R
D	2'-7" x 4'-2"	DH see specs
E	1'-6" x 3'-2"	"
F	2'-6" x 2'-9"	231B Casement
G	3'-0" x 3'-2"	DH see specs
H	2'-0" x 5'-5"	Fixed see specs

- **Presentation drawing**—Drawing having many of the features of a photograph (see Figure 2); drawn by the architect to interest clients

Figure 2: Sample presentation drawing



- **Structural drawing**—Drawing by a structural engineer or architect; may accompany the working plans and give important information about the structure's foundation, skeleton, and floor systems

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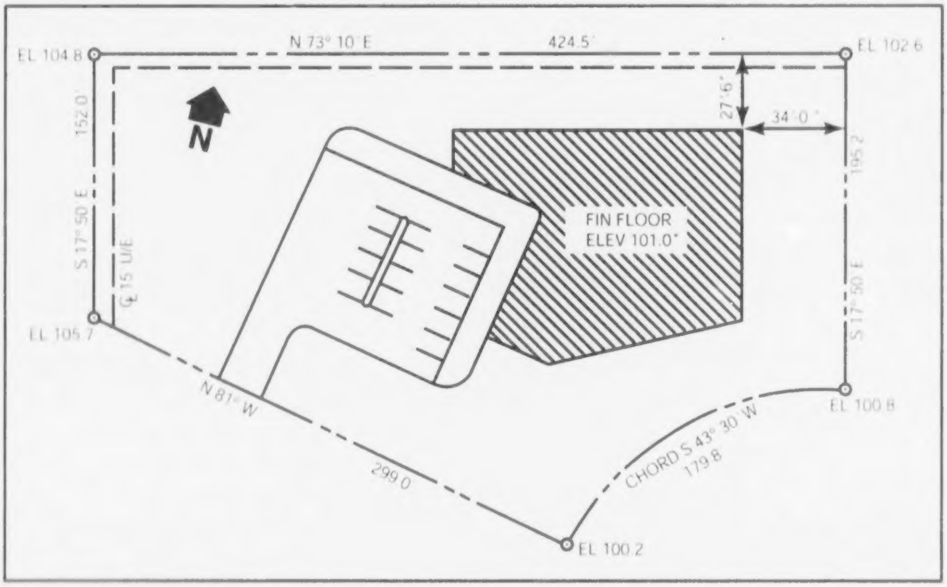
Description of types of drawings usually included in a set of working drawings

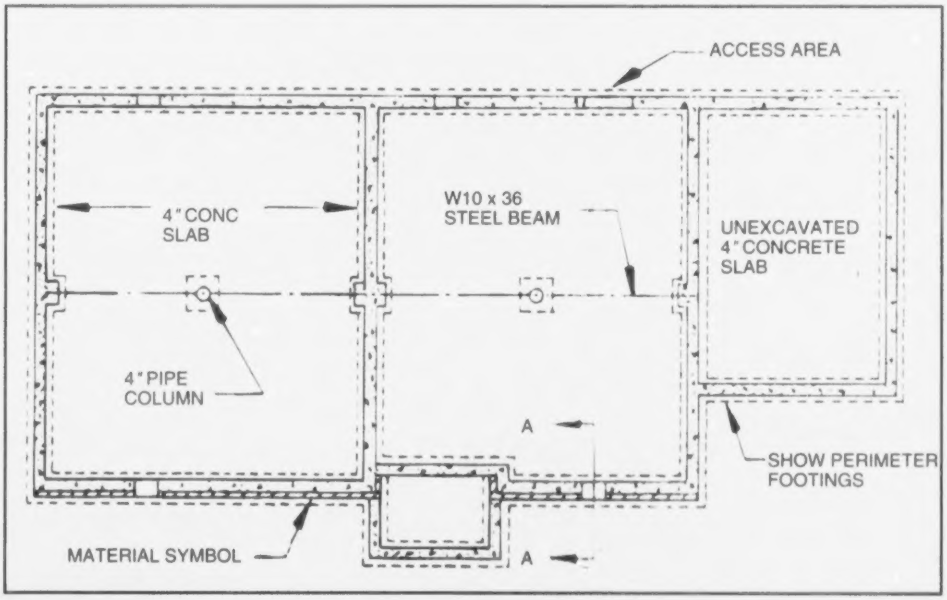
- **Plot plan** (also called a *site plan*)—Horizontal view showing where a structure is to be located on a site (see Figure 3)

Figure 3: Sample plot plan


EL 104.8
N 73° 10' E
424.5'
EL 102.6
27'6"
34'0"
N
152.0'
S 17° 50' E
℄ 15' U/E
195.2'
FIN FLOOR
ELEV 101.0'
S 17° 50' E
EL 105.7
N 81° W
299.0'
CHORD S 43° 30' W
179.8'
EL 100.8
EL 100.2

- **Foundation plan**—Horizontal view of an entire substructure below the first floor or frame of a structure (see Figure 4)

Figure 4: Sample foundation plan


ACCESS AREA
4" CONC
SLAB
W10 x 36
STEEL BEAM
UNEXCAVATED
4" CONCRETE
SLAB
4" PIPE
COLUMN
A
SHOW PERIMETER
FOOTINGS
MATERIAL SYMBOL
A

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- **Floor plan**—Horizontal view of a structure, showing the length and breadth of the structure and the layout of the rooms on that floor (see Figure 5)

  Of all the drawings that comprise a full set of plans, none is more important than the floor plan. The floor plan includes not only the greatest amount of information but is the basis for all the other drawings that must be developed. A floor plan is constructed by taking an imaginary cutting plane through the structure about half way (commonly 48 inches) between the floor and ceiling, and then drawing a plan view of what remains below the cutting plane (see Figure 6).

Figure 5: Sample floor plan

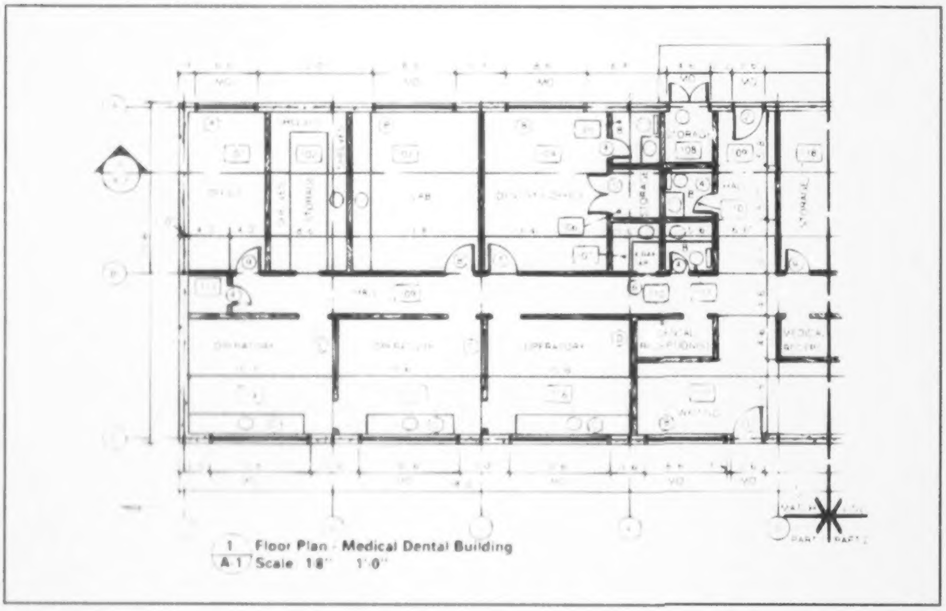
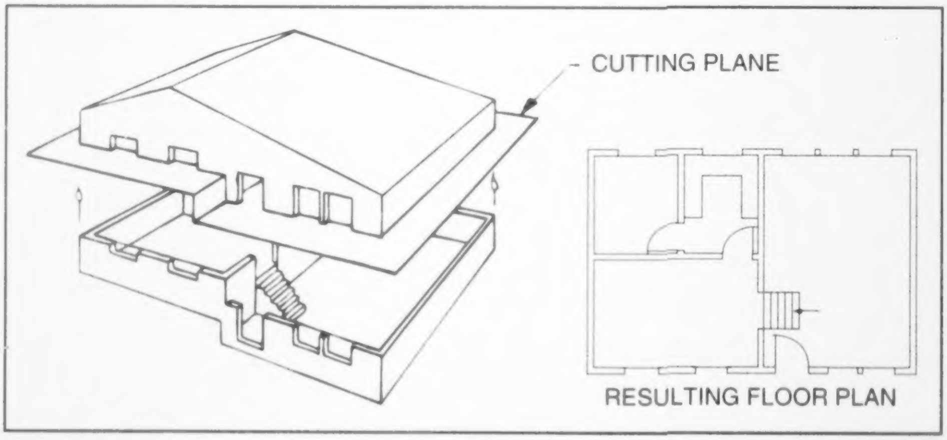

STORAGE
LAB
OPERATORY
OPERATORY
OPERATORY
WAITING
MEDICAL
STORAGE
1 Floor Plan - Medical Dental Building
A 1 Scale 1/8" 1'0"

Figure 6: Constructing a floor plan


CUTTING PLANE
RESULTING FLOOR PLAN

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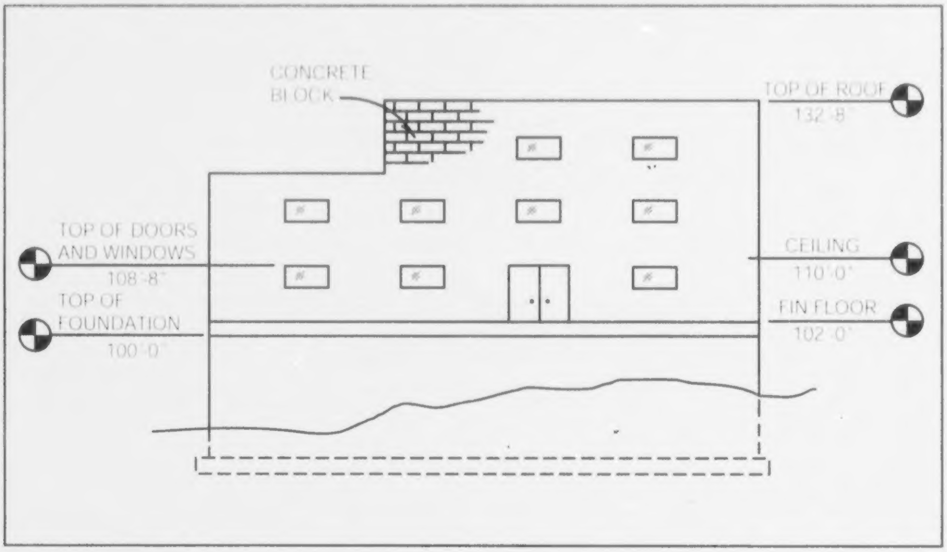
- **Elevation**—Vertical two-dimensional view showing the shape and design of each of the exterior or interior faces of a structure (see Figure 7)

Figure 7: Sample elevation


CONCRETE
BLOCK
TOP OF ROOF
132'-8"
TOP OF DOORS
AND WINDOWS
108'-8"
CEILING
110'-0"
TOP OF
FOUNDATION
100'-0"
FIN FLOOR
102'-0"

- **Section**—Cut-away view through an object or wall to show its interior makeup (see Figures 8 and 9)

  Section drawings may be drawn on the same sheet as an elevation or plan drawing, or may appear on a separate sheet in the set of drawings.

Figure 8: Constructing a section view

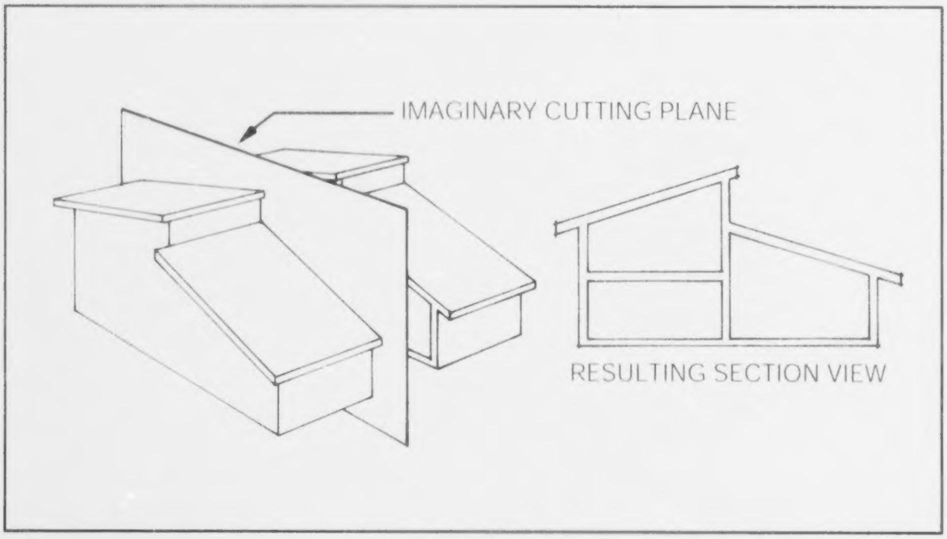

IMAGINARY CUTTING PLANE
RESULTING SECTION VIEW

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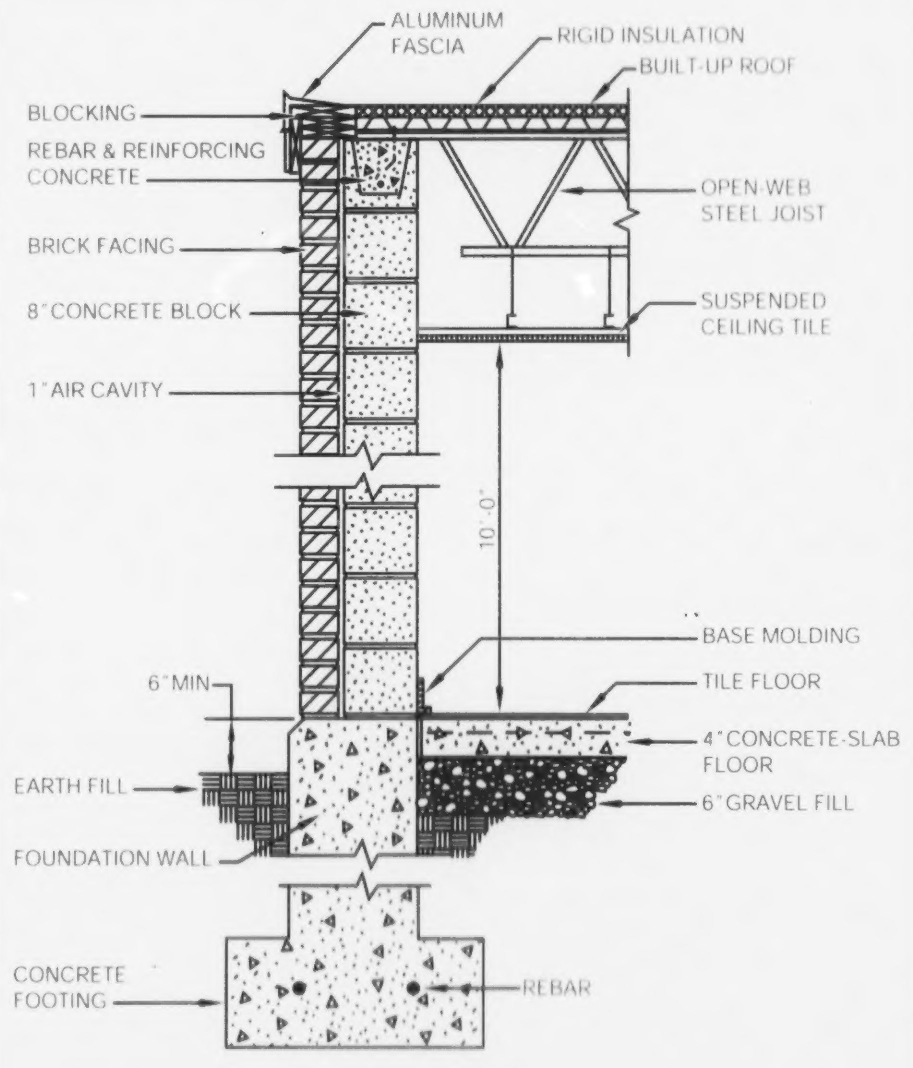
Figure 9: Sample wall section


ALUMINUM FASCIA
RIGID INSULATION
BUILT-UP ROOF
BLOCKING
REBAR & REINFORCING CONCRETE
OPEN-WEB STEEL JOIST
BRICK FACING
8" CONCRETE BLOCK
SUSPENDED CEILING TILE
1" AIR CAVITY
10'-0"
BASE MOLDING
6" MIN
TILE FLOOR
4" CONCRETE-SLAB FLOOR
EARTH FILL
6" GRAVEL FILL
FOUNDATION WALL
CONCRETE FOOTING
REBAR

- **Detail**—Large-scale graphic of part of another drawing, indicating special features of design, location, and composition and the correlation of the elements and materials shown (see Figure 10)

Detail drawings often use the cut-away section view to show aspects that are too small to be shown in sufficient detail on plan or elevation drawings. Like section drawings, detail drawings may be drawn on the same sheet as an elevation or plan drawing or may appear on a separate sheet in the set of drawings.

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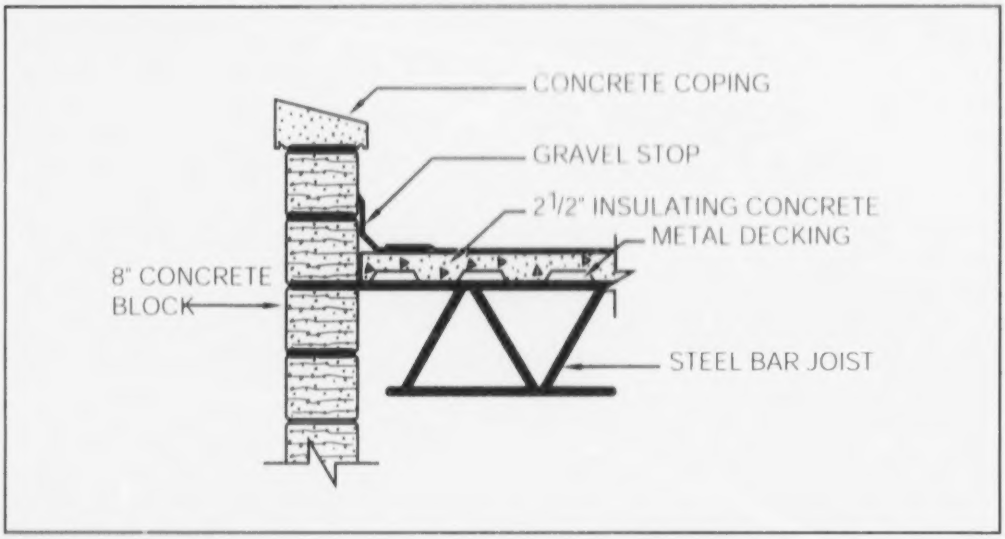
Figure 10: Cornice detail drawn to show how an exterior wall intersects the structure's roofing system and any roof overhang that occurs at that intersection



Standard sequence of drawings in a set of working drawings

The packaging of a set of working drawings is very specific in its arrangement. This arrangement helps a reader locate a certain section of the drawings before proceeding to a particular document.

- **Cover sheet** (title sheet)

  The cover sheet is the first sheet in a set of plans. It lists the project name, the client's name, and the address of the structure; provides a table of contents that indexes the sheets contained in the working drawings; and lists schedule of notations, symbols, and abbreviations used in the drawings. Many times, a pictorial rendering of the project will also appear on the cover sheet.

- **Architectural drawings**

  Architectural drawings include a site plan, floor plans, schedules, roof plan, elevations, sections, and details

- **Structural drawings**

  Structural drawings include foundation plans, structural sections, framing plans, and structural details.

- **Mechanical drawings**

  Mechanical drawings include plumbing plans, plumbing details, mechanical fixtures, HVAC plans, and HVAC details.

- **Electrical drawings**

  Electrical drawings include power-distribution plans, communication systems, fire-protection systems, lighting plans, fixture plans, fixture schedules, and electrical details.

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Description of the drawing-identification system used in a set of working drawings

A drawing-identification system has been established to help a reader locate any desired drawing within a complete set of working drawings. The statements below describe the established system.

- The drawing-identification system consists of an alphanumeric callout placed on the title block located on each drawing (see the "alphanumeric callout" label in Figure 11).
- The letter in the callout relates directly to the type of drawing shown on the sheet.

  Example: The title block shown in Figure 11 appears on an architectural drawing. Architectural-drawing callouts begin with the letter A.

- The number in the callout indicates the sequence of the sheet within the section where the drawing appears.

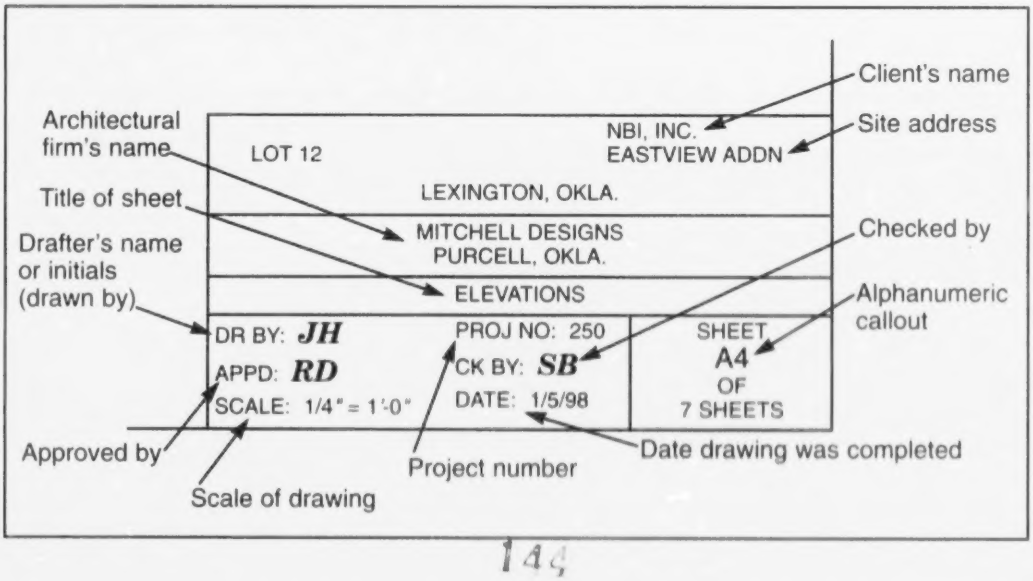
  Examples: page 1, page 2, or page 3

- Therefore, architectural-drawing callouts are numbered A1, A2, A3, etc.; structural-drawing callouts are numbered S1, S2, S3, etc.; mechanical-drawing callouts are numbered M1, M2, M3, etc.; and electrical callouts are numbered E1, E2, E3, etc.

Components of a title block

Every sheet in a working set of drawings includes a title block. The title block is usually located in the lower right-hand corner of the drawing but may sometimes be extended along the entire right side of the drawing. Figure 11 shows the components that should be provided on a title block.

Figure 11: Sample title block

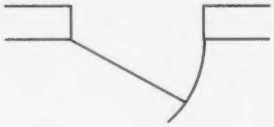

Client's name
Architectural firm's name
NBI, INC.
Site address
LOT 12
EASTVIEW ADDN
Title of sheet
LEXINGTON, OKLA.
MITCHELL DESIGNS
PURCELL, OKLA.
Checked by
Drafter's name or initials (drawn by)
ELEVATIONS
Alphanumeric callout
DR BY: JH
PROJ NO: 250
SHEET
APPD: RD
CK BY: SB
A4
OF
SCALE: 1/4" = 1'-0"
DATE: 1/5/98
7 SHEETS
Approved by
Date drawing was completed
Project number
Scale of drawing

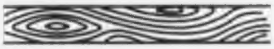
Student Supplement 2

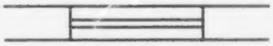
Plan symbols used on floor plans

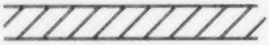
Symbols are used on drawings to provide simple representations of often-complex objects, therefore allowing a quick understanding of the layout and construction of a structure. Table 1 below shows the symbols commonly used on floor-plan drawings.

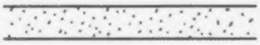
Table 1: Floor-plan symbols

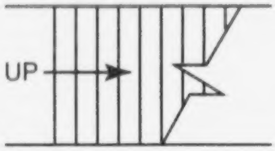

Door*


Wood

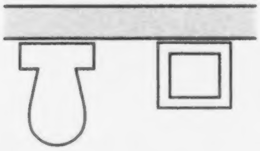

Window (general)**

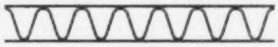

Brick


Concrete



Stairway


Bathroom fixtures


Metal stud to drywall

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* Different types of doors may have slightly different symbols.
** Different types of windows may have slightly different symbols.

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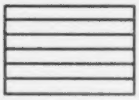
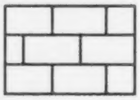
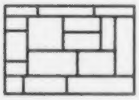
Plan symbols used on elevation drawings

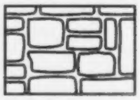
The symbols shown in Table 2 below are commonly used on elevation drawings to represent natural and man-made construction materials.

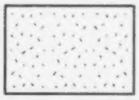
Table 2: Elevation-drawing symbols

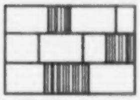

Brick

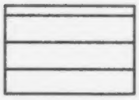

Concrete block

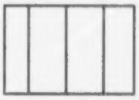

Cut stone

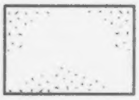

Rock

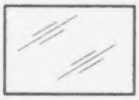

Concrete

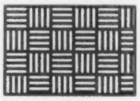

Wood shingle


Horizontal wood siding


Vertical wood siding


Stucco


Glass


Earth

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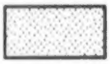
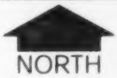
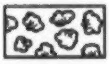
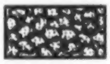
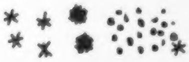
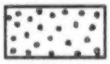
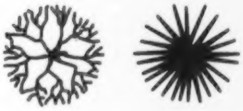
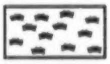
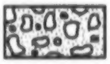
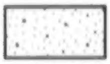
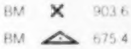
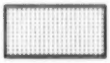
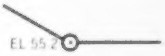
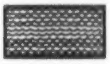
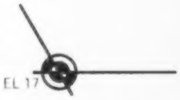
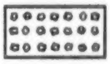
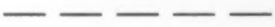
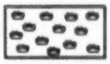
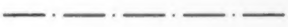
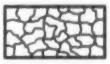
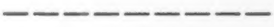
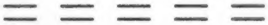
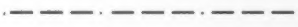
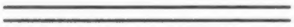
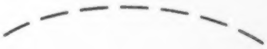
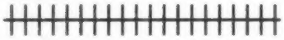
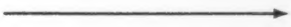
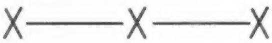
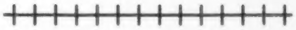
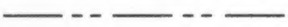
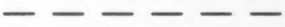
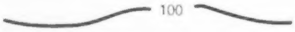
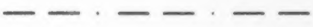
Symbols commonly used on plot plans

The symbols shown in Table 3 below are commonly used on plot-plan drawings to represent natural and man-made objects appearing on a site.

Table 3: Plot-plan symbols

Sand		North arrow	
Open woodland		Well	
Dense forest		Ground cover	
Small irregularly spaced trees		Trees	
Tall grass			
Large stones		Spot elevation	+ EL 109.1
Gravel		Benchmarks	
Cultivated area		Property corner	
Water		Property corner with monument	
Orchard		Sanitary sewer	
Marsh		Gas line	
Dry cracked clay		Water line	
Unpaved road		Power line	
Paved road		Proposed contour	
Railroad tracks		Valley	
Fence		Sewer tile	
Property line		Septic field	
Existing contour		Telephone	

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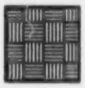
Student Supplement 2

Symbols commonly used on section drawings

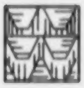
Symbols used to define building materials that have been cut through are called *section symbols*. Each symbol is a specific representation for a given building material. However, since a floor-plan drawing is actually a horizontal section, many of the section symbols are the same as those you learned for floor-plan drawings.

Table 4: Section-drawing symbols

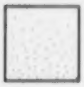
Earth



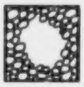
Rock



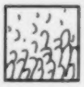
Sand



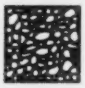
Gravel



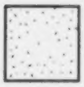
Cinders



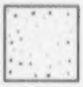
Aggregate



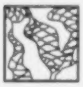
Cut stone—ashlar



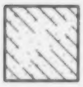
Cut stone—rough



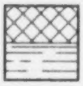
Marble



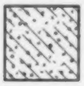
Flagstone



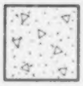
Cut slate



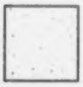
Random rubble



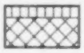
Concrete



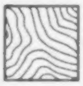
Limestone



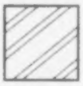
Ceramic tile



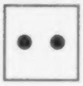
Wood



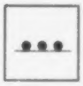
Steel



Steel reinforcing bars



Welded wire mesh



Exploring Construction Technology

Assignment Sheet 5—Evaluate a Structure

Name ______________________ Date ____________

Evaluation criteria	**Rating**
Directions have been followed.	______
Length and width dimensions are accurate and square-footage computations are accurate.	______
First floor-plan drawing is neat, accurate, and to scale.	______
Notes taken during family meeting are relevant and well thought out.	______
Revised floor-plan drawing is neat, accurate, to scale, and incorporates the ideas and suggestions presented in the family-meeting notes.	______
Overall rating	______

Evaluator's comments ______________________________________

____

____

Introduction

In Objective 4 of the information sheet, you learned that the fourth stage in a basic technology systems model is *feedback*—the return to the input stage with evaluative or corrective information about the system processes and output. And, in a construction system, feedback is provided by things such as tests and inspections during and after the construction of a structure, the response of people who use a structure, and the need for service and repair of the structure.

In this assignment sheet, you will provide feedback (evaluative information) about a residential structure with which you are very familiar—your own home.

Exercise

Activity checklist

Put a checkmark on the blank line before each activity below and on the next page as you complete it.

______ 1. **Review** the information in Student Supplement 2, "Introduction to Working Drawings," which begins on page 37.

Assignment Sheet 5

_______ 2. **Measure to the nearest inch** the width and length dimensions of each of the rooms in your home. Then, on a separate sheet of paper, make a dimensions chart similar to the sample chart in Figure 1 on page 51 to record the dimensions of each room.

_______ 3. From the length and width measurements you made in Step 2, **compute the area** (square footage) of each of the rooms in your home, and **record the area** of each room on the chart you created in Step 2.

_______ 4. **Compute the total area of your home**, and then, **record** the total area of the home on the chart you created in Step 2.

_______ 5. **Draw a to-scale floor-plan sketch** of your home. Check with your instructor to determine how you should complete your to-scale drawing—manually or with CAD equipment.

_______ 6. **Turn in** your chart and your to-scale drawing to your instructor for evaluation.

_______ 7. Your instructor will return your chart and your to-scale drawing with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return** your chart and your drawing to your instructor for **final evaluation**.

_______ 8. **Hold a family meeting** with all the members of your family. During this meeting, discuss with your family how well your home meets your family's needs and what changes or additions are needed to meet those needs better. Also, discuss the expenses for service and repair of the structure that have occurred during the past two-year period. **Record as notes** the ideas presented by your family members on a separate sheet(s) of paper and label these notes "Family-Meeting Notes."

_______ 9. Using the information from your family-meeting notes as feedback, **complete a revised to-scale floor-plan sketch** that incorporates the changes or additions that would improve your home to better meet your family's needs. Check with your instructor to determine how to complete your drawing—manually or with CAD equipment.

_______ 10. **Turn in** your family-meeting notes and your revised to-scale drawing to your instructor for evaluation.

_______ 11. Your instructor will return your notes and your to-scale drawing with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return** your notes and your drawing to your instructor for **final evaluation**.

Assignment Sheet 5

Figure 1: Sample dimensions chart

Name of room	Dimensions (width x length)	Area (sq. ft.)
1. Kitchen		
2. Dining room		
3. Living room		
4. Family room		
5. Recreation room		
6. Master bedroom		
7. Bedroom 2		
8. Bedroom 3		
9. Bedroom 4		
10. Den/study		
11. Bath 1		
12. Bath 2		
13. Utility room		
14. Storeroom		
15. Garage		
16. Foyer		
17. Hall 1		
18. Hall 2		
19. Stairwell		
Other (specify)		
20.		
21.		
22.		
23.		
24.		
	Total area	

Exploring Construction Technology

Lab Activity Sheet 1—Design, Build, Test, and Evaluate a Model Substructure

Introduction

In Lab Activity Sheet 1, Lab Activity Sheet 2, and Lab Activity Sheet 3, you will practice your creative and logical thinking skills and use the information you have learned about the construction process to design, build, and test some model structures.

In this lab activity, you will design, build, test, and evaluate a model substructure. You will accomplish this task by following the guidelines listed in the procedure steps below.

Procedure

Put a checkmark on the blank line before each step below as you complete it.

_______ 1. Read the information presented in Student Supplement 3, "Introduction to Substructures," which begins on page 59, and review Student Supplement 2, "Introduction to Working Drawings."

_______ 2. Your instructor will divide your class into groups of two, and you and your partner will study the rules and regulations for this activity, which are presented below.

Rules and regulations

- Your instructor will provide you with a single ¾-inch wood dowel that is 4 feet long. At the top of the dowel will be a receptacle that will accommodate a basketball.

  Your instructor will also provide you with a box that is 2 feet square and filled with dry sand to a depth of 12 inches.

  You and your partner must incorporate the wood dowel/basketball receptacle into the design of a substructure that will fit into the 2-foot square, sand-filled box.

- The design of your substructure must meet the following specifications:
  - The wood dowel/basketball receptacle may not be attached to your substructure with adhesives or any mechanical fasteners.
  - The combined weight of the substructure and the wood dowel/basketball receptacle may total no more than 4 pounds.
  - The substructure itself can measure no more than 12 inches in height.

Lab Activity Sheet 1

- The maximum weight of the substructure can be no more than 32 ounces.

- When the substructure is set in the box of dry sand, the top of the substructure must be even with the surface of the sand.

- After the substructure has been constructed, the substructure set in the box of dry sand, and the dowel/basketball receptacle attached, it will be tested using the following rules:

  - Your instructor will place a basketball in the receptacle on the wood dowel, position a household fan 2 feet away from the surface of the basketball, and turn the fan on at its highest setting.

  - The substructure must support the wood dowel/basketball receptacle and basketball for 1 full minute. Penalty points will be deducted from the rating if the substructure fails to support the wood dowel/basketball receptacle and basketball for a full minute.

_______ 3. Review the worksheet associated with this lab activity, which begins on page 55.

_______ 4. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for your substructure design and the equipment/materials you have listed for constructing the substructure.

_______ 5. Review the evaluation criteria listed in the performance evaluation (Part C) on the worksheet.

_______ 6. Using the instructor-approved design and equipment/materials list, construct your model substructure.

_______ 7. Have your instructor weigh and measure your substructure, and weigh the basketball. Record these weights/measurements.

_______ 8. Have your instructor test your substructure.

_______ 9. Evaluate the substructure. Complete the computations required in Part B on the worksheet.

_______ 10. Your instructor will rate your performance using the evaluation criteria listed in Part C on the worksheet.

Lab Activity Sheet 1

Worksheet—Design, Build, Test, and Evaluate a Model Substructure

Name ______________________ Attempt number __________

Date ______________________

Part A: **Pre-performance check**

- On a separate sheet(s) of paper, draw a to-scale elevation sketch of your substructure design and write a description of why you selected this type of substructure design and how you believe your substructure will function.

- In the space below or on a separate sheet(s) of paper, list the equipment you will require to construct your substructure.

- In the space below or on a separate sheet(s) of paper, list the materials you will require to construct your substructure, the quantities/amounts of each of the materials you will require, the per-unit cost of each of the materials you will require, and the total cost of the materials.

Instructor's signature ______________________

Lab Activity Sheet 1

Worksheet—Design, Build, Test, and Evaluate a Model Substructure

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Part B: **Substructure evaluation**

Make the computations required in each of the sections below to evaluate your substructure. Show your work in the spaces provided in each section and write your answers on the blanks provided.

- Compute the efficiency rating for your substructure. Use the formula:

  $E = S/B$, where

  E is the efficiency rating,

  S is the weight of the substructure (in ounces), and

  B is the weight of the basketball (in ounces).

  The lower the resulting efficiency rating, the better.

  Efficiency rating ______________________________

- Compute the cost-effectiveness rating of your substructure. Use the formula:

  $E = C/B$, where

  E is the cost-effectiveness rating,

  C is the total cost (in cents) of the materials used to construct the substructure, and

  B is the weight of the basketball (in ounces).

  The lower the rating, the better.

  Cost-effectiveness rating ______________________________

Lab Activity Sheet 1

Worksheet—Design, Build, Test, and Evaluate a Model Substructure

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Part C: **Performance evaluation**

Evaluation criteria	**Rating**
Design of the substructure meets the rules and regulations set for the procedure.	______
Presentation of the design drawing and description of the substructure is neat, accurate, and well organized visually.	______
During the test, the substructure functions according to the rules and regulations set in the procedure.	______
Note to evaluator: Penalty points must be deducted if the substructure fails to support the basketball in the wood dowel/receptacle for a full minute.	
Computations completed in Part B were accurate.	______
Lab clean-up and follow-up actions were satisfactory.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Exploring Construction Technology

Student Supplement 3—Introduction to Substructures

Introduction

In Objective 6 in the information sheet, you learned that a structural system is the weight-bearing frame of a structure and that the major structural systems in any structure are the substructure and the superstructure. You also learned that the substructure is the foundation that supports the superstructure, that substructures can be made of various materials (concrete, wood, steel), and that, in on-earth structures, substructures are usually constructed below ground.

In this student supplement, you will learn more about the substructures used in on-earth structures:

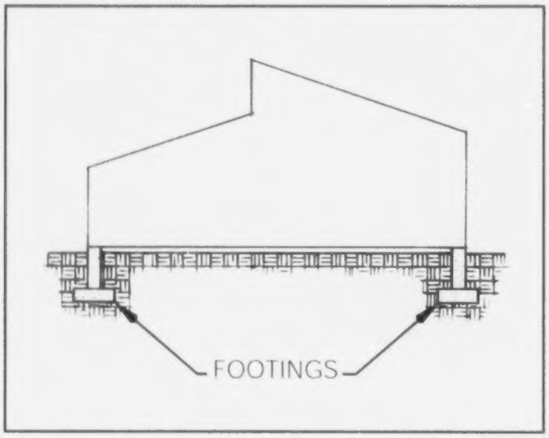
- the basic components of a substructure (footing and foundation wall) and their purposes, and
- the types of footings used in substructures.

Basic components of a substructure

- **Footing**—Base of the substructure; acts to distribute the structure's weight load directly to the earth (see Figure 1)

  The footing, which sits at the very base of the foundation wall, acts to evenly distribute a structure's weight over a large area. Almost all footings are concrete so as to enable the footing to maintain firm contact with the earth's surface.

  Figure 1: Footings



- **Foundation wall**—Vertical component of the substructure; acts to transmit a structure's weight load from the superstructure to the footings and the base of the superstructure

  Foundation walls are normally constructed of cast-in-place concrete or masonry products such as concrete block (see Figure 2 on the next page).

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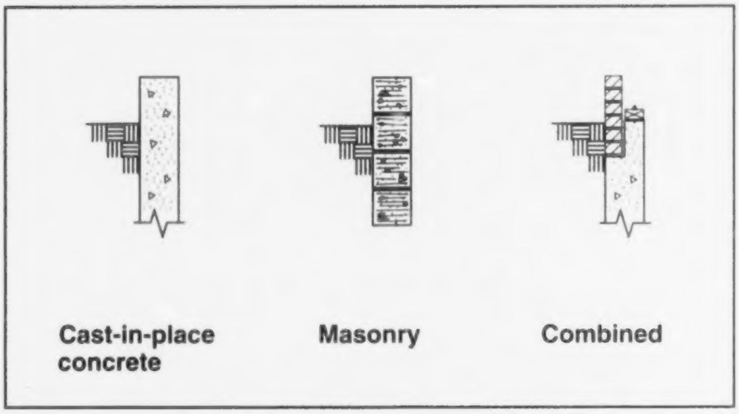
Figure 2: Foundation walls



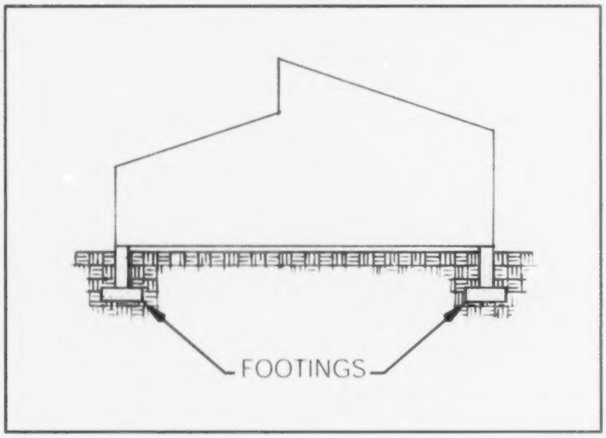
Types of footings

Four types of footings are commonly used in on-earth structures: spread footings, slab footings, column footings, and pile footings.

- **Spread**

  A spread footing, sometimes called a *T-footing* or *continuous footing*, is usually rectangular and typically the same height but twice as wide as the foundation wall. When placed at the base of a foundation wall, the footing spreads out and forms an inverted-T shape with the foundation wall (see Figure 3), hence the footing name *spread footing*.

  Figure 3: Spread footing

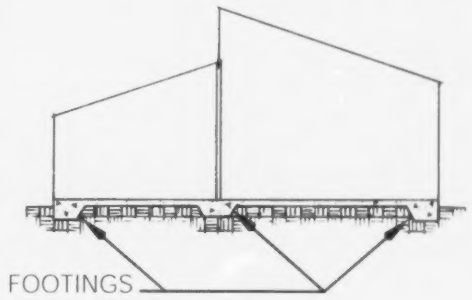


- **Slab**

  A slab foundation, sometimes called a *grade-beam footing*, combines the footing and the foundation into a monolithic slab of concrete (a large, single piece of concrete). The slab is widened and/or deepened where extra foundation support is required, such as at exterior walls or for interior column supports (see Figure 4 on the next page).

Student Supplement 3

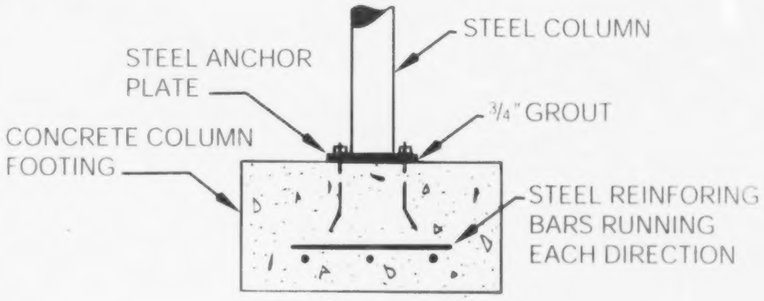
Figure 4: Slab footing



- **Column**

Column footings have rectangular concrete support bases (see Figure 5) that provide load distribution from interior building columns and other load-bearing supports. This type of footing is usually strengthened with steel reinforcing placed inside the footing. Footings are usually entirely concrete, while columns may be steel, wood, or brick.

Figure 5: Column footing


STEEL COLUMN
STEEL ANCHOR PLATE
3/4" GROUT
CONCRETE COLUMN FOOTING
STEEL REINFORING BARS RUNNING EACH DIRECTION

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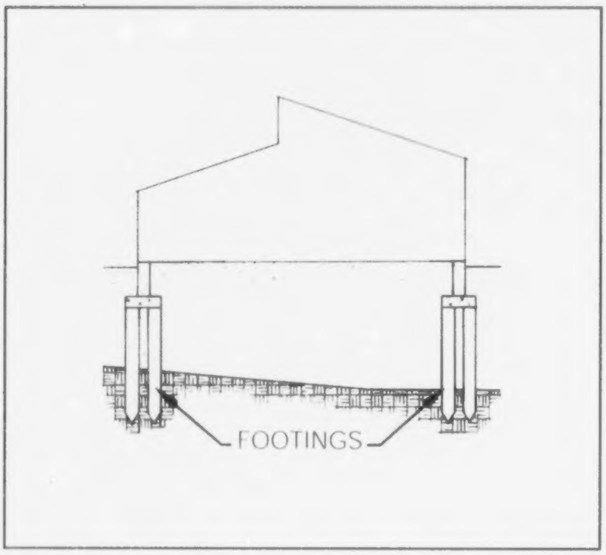
- **Pile**

  Pile footings are used when soil conditions are fragile, such as in sand or marsh areas or near bodies of water. In such areas, long, narrow supports made of steel, wood, or concrete are driven through the soft soil until they reach compacted soil or bedrock. Then, a spread footing (called a *pile cap*) is placed over the pile footing (see Figure 6).

Figure 6: Pile footing



Exploring Construction Technology

Lab Activity Sheet 2—Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure

Introduction

In this lab activity, you will design, build, test, and evaluate a model truss-bridge superstructure. You will accomplish this task by following the guidelines listed in the procedure steps below. By completing this activity, you will learn the principles of constructing framed superstructures and the relationship between the materials used and the truss design.

Procedure

Put a checkmark on the blank line before each step below as you complete it.

_______ 1. Read the information presented in Student Supplement 4, "Introduction to Truss-Bridge Superstructures," which begins on page 71.

_______ 2. Your instructor will divide your class into groups of two, and you and your partner will study the rules and regulations for this activity, which are presented below.

Rules and regulations

- Your instructor will provide you with the following equipment and materials to construct a model truss-bridge superstructure:
  - basswood strips
  - white glue
  - a utility knife and blade
  - straight pins
  - a ruler

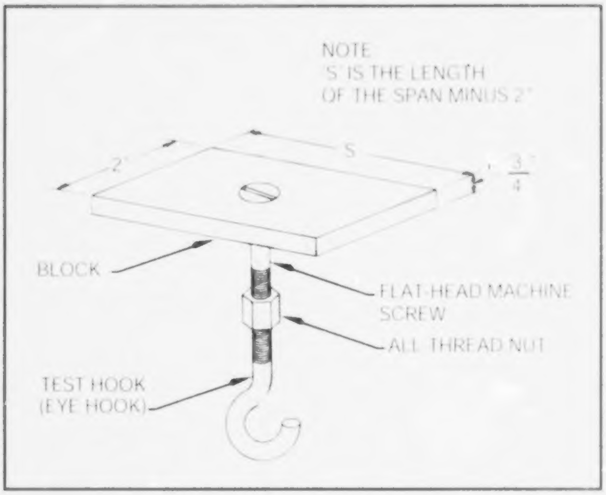
  Your instructor will also provide you with a per-unit price for each basswood strip you use to complete your model truss-bridge superstructure.

- Your instructor will have you examine a testing frame, test block, and test hook that he or she will use to stress test your completed model truss-bridge superstructure.

  You and your partner must design your model truss-bridge superstructure to fit in the span of the testing frame and to accommodate the test block (see Figure 1 on the next page) on its roadbed so that the machine screw can protrude through the roadbed of the superstructure.

Lab Activity Sheet 2

Figure 1: Test block



- The design of your model truss-bridge superstructure must also meet the following specifications:
  - — The truss-bridge superstructure must be symmetrical in all respects to a vertical axis through its geometric center.
  - — The top of the roadway must be at a height no greater than 30 mm above grade. *Grade* is defined as the level of the top surface of the testing frame.
  - — No part of the bridge may extend below the grade.
  - — The finished truss-bridge superstructure must be between 250 mm and 300 mm in length.
  - — The finished truss-bridge superstructure must be at least 50 mm wide.
  - — The finished truss-bridge superstructure must be at least 50 mm in height.
  - — The finished truss-bridge superstructure must weigh no more than 100 grams.
- After the truss-bridge superstructure has been constructed, the superstructure placed in the testing frame, and the test block and hook attached, the superstructure will be tested using the following rule:
  - — Your instructor will suspend an empty 5-gallon bucket on the test hook and will pour clean, dry sand by cupfuls into the suspended bucket until the weight breaks the truss-bridge superstructure.

Lab Activity Sheet 2

_______ 3. Review the worksheet associated with this lab activity, which begins on page 67.

_______ 4. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for your superstructure design.

_______ 5. Review the evaluation criteria listed in the performance evaluation (Part C) on the worksheet.

_______ 6. Using the instructor-approved design and the equipment/materials your instructor has provided, construct your model superstructure.

_______ 7. Have your instructor weigh and measure your completed superstructure.

_______ 8. Have your instructor test your completed superstructure on the testing frame and weigh the sand and the bucket when the superstructure breaks.

_______ 9. Evaluate the superstructure. Complete the computations required in Part B on the worksheet.

_______ 10. Your instructor will rate your performance using the evaluation criteria listed in Part C on the worksheet.

Lab Activity Sheet 2

Worksheet—Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure

Name ______________________ Attempt number __________

Date ______________________

Part A: **Pre-performance check**

Complete the following information concerning the design of the superstructure.

- On a separate sheet(s) of paper, draw a to-scale elevation sketch of your truss-bridge superstructure design and write a description of why you selected this type of superstructure design and how you believe your superstructure will function.

Instructor's signature ______________________

Lab Activity Sheet 2

Worksheet—Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure

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Part B: **Superstructure evaluation**

Make the computations required in each of the sections below to evaluate your superstructure. Show your work on a separate sheet of paper and write your answers on the blanks provided below.

- Compute the efficiency rating for your superstructure. Use the formula:

  $E = L/B$, where

  E is the efficiency rating,

  L is the weight* of the load that the superstructure supported, and

  B is the weight* of the truss-bridge superstructure.

  The higher the resulting efficiency rating, the better.

  Efficiency rating ____________________

- In the blank below, list the total cost (in cents) of the basswood strips used to construct your model truss-bridge superstructure.

  Total cost ____________________

- Compute the cost-effectiveness rating or your superstructure. Use the formula:

  $E = L/C$, where

  E is the cost-effectiveness rating,

  L is the weight* of the load that the superstructure supported, and

  C is the total cost (in cents) of the materials used to construct the truss-bridge superstructure.

  The higher the rating, the better.

  Cost-effectiveness rating ____________________

*Note: Use metric measurements for weight in your computations.

Lab Activity Sheet 2

Worksheet—Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure

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Part C: Performance evaluation

Evaluation criteria	**Rating**
Design of the superstructure meets the rules and regulations set for the procedure.	______
Presentation of the design drawing and description of the superstructure is neat, accurate, and well organized visually.	______
During the test, the superstructure functions according to the rules and regulations set in the procedure.	______
Computations completed in Part B were accurate.	______
Lab clean-up and follow-up actions were satisfactory.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Exploring Construction Technology

Student Supplement 4—Introduction to Truss-Bridge Superstructures

Introduction

In Objective 6 in the information sheet, you learned that the major structural systems in any structure are the substructure and the superstructure. You also learned that the superstructure is any portion of a structure that rests upon the substructure.

In this student supplement, you will learn a little more about the superstructures used for on-earth structures—especially truss superstructures, which is the type of superstructure you will build and test in Lab Activity Sheet 2, "Design, Build, Test, and Evaluate a Model Truss-Bridge Superstructure."

You will learn about

- the basic types of superstructures (mass, bearing-wall, and framed) and their descriptions,
- the definition of a truss, and
- the types of truss-bridge superstructures.

Basic types of superstructures

- **Mass superstructure**

  A mass superstructure is comprised of large amounts of materials over a great area with little or no internal openings. Dams and retaining walls are examples of mass superstructures.

- **Bearing-wall superstructure**

  A bearing-wall superstructure is comprised of continuous support walls that are normally made of masonry materials.

- **Framed superstructure**

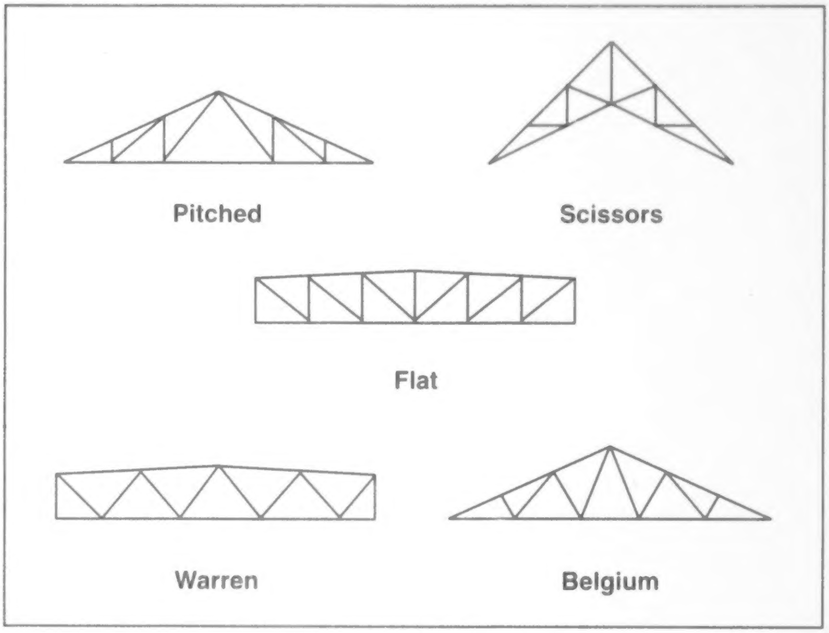
  A framed superstructure is comprised of steel, concrete, or wood columns or posts that create a support skeleton. A framed superstructure supports all of the exterior materials used to enclose a structure, and of the three types of superstructures, allows for the greatest amount of design freedom.

Definition of the term *truss*

Trusses are often used in constructing framed superstructures. A *truss* is a structural member constructed of components placed in a triangular arrangement. You have probably seen the trusses that are used in residential construction in the superstructures of houses to support the roof. Some common roof-truss designs are shown in Figure 1 on the next page.

Student Supplement 4

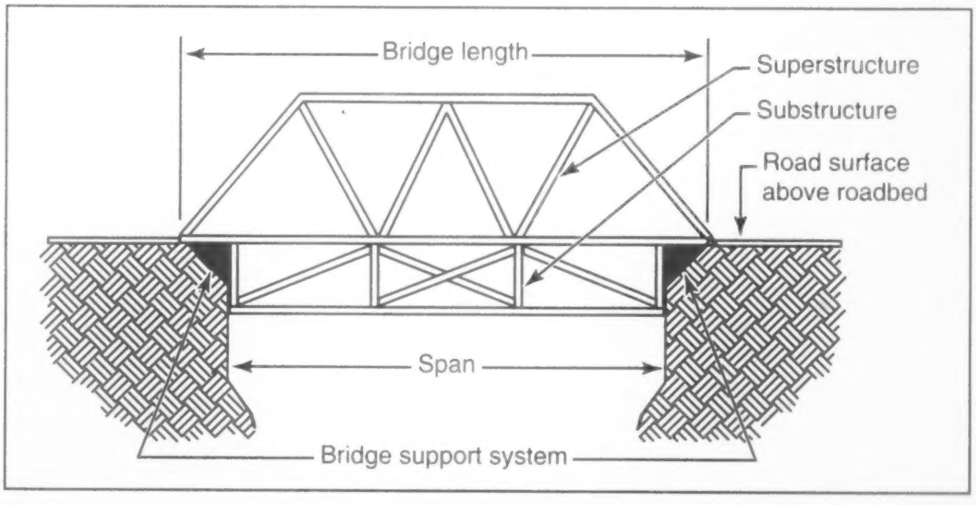
Figure 1: Common roof trusses


Pitched
Scissors
Flat
Warren
Belgium

Types of truss-bridge superstructures

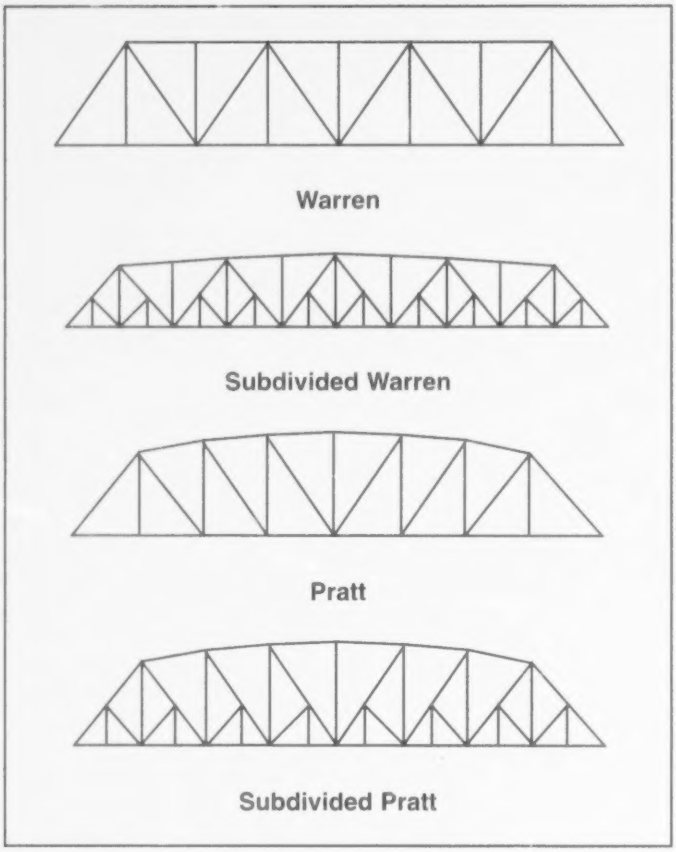
You have probably also seen the trusses that are used in civil construction as you drive on the nation's highways—truss bridges (see Figure 2). The superstructures (and sometimes also the substructures) of truss bridges are made by connecting long, straight pieces of wood, steel, or aluminum into the triangular shapes commonly associated with truss construction. Several types of truss-bridge superstructure designs are shown in Figure 3 on the next page.

Figure 2: Truss bridge


Bridge length
Superstructure
Substructure
Road surface above roadbed
Span
Bridge support system

Student Supplement 4

Figure 3: Types of truss-bridge superstructure designs



Warren

Subdivided Warren

Pratt

Subdivided Pratt

Truss bridges are like insects. Their skeletons—or frames—are on the outside. In fact, many truss bridges consist entirely of a frame and even their roadways are an integral part of the frame (see Figure 2). Trusses must be carefully designed to span great distances and withstand tension and compression stresses.

Exploring Construction Technology

Lab Activity Sheet 3—Design and Build a Model Modular Structure

Introduction As you learned in Objective 9 of the information sheet, one of the emerging construction technologies is modular construction. In modular construction, the large components of a structure or *modules*, such as entire rooms or sections of a structure, are constructed at a factory and each module uses a structural system based on a 4-inch measurement for laying out the placement of the structural members. Modular construction offers builders the advantages of an assembly line's efficiency and quality control, which result in better structures at lower costs.

Procedure Put a checkmark on the blank line before each step below as you complete it.

_______ 1. Review Objective 9 in the information sheet and the information presented in Student Supplement 2, "Introduction to Working Drawings."

_______ 2. Your instructor will divide your class into groups of two, and you and your partner will study the rules and regulations for this activity, which are presented below.

Rules and regulations

- Your instructor will provide your group with the working drawings that were used in constructing his or her technology-education classroom and laboratory.
- You and your group partner must adapt the rooms or the large sections of the working drawings of the classroom and laboratory to working drawings for modules based on a scale of either 1:24 (½ inch = 1 foot) or 1:48 (¼ inch = 1 foot).

_______ 3. Review the worksheet associated with this lab activity, which begins on page 77.

_______ 4. Check with your instructor to determine how you should complete your to-scale working drawings—manually or with CAD equipment.

_______ 5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the working drawings and the equipment/materials list for your modular design.

_______ 6. Using your instructor-approved working drawings and the equipment/materials list your instructor has also approved, build your model modular structure.

_______ 7. Your instructor will rate your performance using the evaluation criteria listed in Part B on the worksheet.

Lab Activity Sheet 3

Worksheet—Design and Build a Model Modular Structure

Name ______________________ Attempt number __________

Date ______________________

Part A: **Pre-performance check**

Complete the following information concerning the design of the modular structure.

- On a separate sheet(s) of paper, draw to-scale working drawings of your model modular-structure design for your technology education classroom. Your finished model should be constructed at a scale of 1:24 (½ inch = 1 foot) or 1:48 (¼ inch = 1 foot).

- In the space below or on separate sheet(s) of paper, list the equipment you will require to construct your model modular structure.

- In the space below or on separate sheet(s) of paper, list the materials you will require to construct your model modular structure, the quantities/amounts of each of the materials you will require, the per-unit cost of each of the materials you will require, and the total cost of the materials.

Instructor's signature ______________________

Lab Activity Sheet 3

Worksheet—Design and Build a Model Modular Structure

Part B: Performance evaluation

Evaluation criteria	**Rating**
The working drawings used in the design of the modular structure meet the rules and regulations set for the procedure.	______
Presentation of the design drawings is neat, accurate, and well organized visually.	______
Completed model is to scale.	______
Lab clean-up and follow-up actions were satisfactory.	______
Overall rating	______

Evaluator's comments ____

____

____